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JOINT STRATEGIES FOR URBAN TRANSPORTATION, AIR QUALITY AND ENERGY CONSERVATION

JOINT ACTION PROGRAMS

INTERPLAN CORPORATION

PREPARED FOR
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Joint Action Programs

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JOINT STRATEGIES FOR URBAN TRANSPORTATION, AIR QUALITY AND ENERGY CONSERVATION

Joint Action Programs

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PREFACE

This study represents the joint efforts of three Federal agencies to develop an integrated approach for resolving three issues of national concern: urban mobility, air pollution and the scarcity of petroleum resources. All three issues are intimately tied to the preeminence of the automobile in the late twentieth-century American society.

One by one, government agencies have been created to direct Federal action on each of these issues. The administrative independence of these agencies, however, should not obscure the interdependence of the problems or the remedial actions that must be formulated. Thus, it was felt, the three agencies should consider their missions from a joint perspective to determine the opportunities for complementary strategies and co-operative actions.

The present report is the result of this inter-agency cooperation.

INTERPLAN DISCLAIMER

The contents of this report reflect the views of INTERPLAN Corporation, which is responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views of the Department of Transportation. This report does not constitute a standard specification or regulation.

UMTA NOTE

The enactment of the National Mass Transportation Act of 1974 has permitted UMTA to respond to a wider spectrum of urban transportation needs than was previously possible. For instance, the provision of operating assistance now offers a favorable climate for the growth of low-capital service improvements. The text of this report does not always reflect this change, since the preparation of the report predates this legislation. Of particular note is UMTA's encouragement of private and public para-transit service.

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16. Abstract

Problems of mobility in the cities, the quality of urban air, and transportation-related energy consumption constitute major issues of national concern. This report represents the joint efforts of UMTA, EPA and FEA to develop an integrated approach for resolving problems created by traffic congestion, air pollution, and petroleum shortages. The purposes of this report were to: (1) identify all principal strategies and actions which impact on each of the agencies' transportation-related goals; (2) systematically elucidate the interrealtionships among them; and (3) devise a way of isolating those groups of strategies and actions whose total impacts would be synergistically enhanced if implemented jointly. The report represents the culmination of the study effort to attain these objectives. In Part I, the basic relationships among the strategies and actions are summarized in a matrix display. Each item is ranked to access its impact on six subgoals, or phenomena, in the near or long term: improved auto alternatives, improved vehicular flow; reduced auto use; reduced travel demand; reduced vehicular emissions; and reduced vehicular petroleum consumption. Two synergistic joint action programs are presented. Part II contains an information review of experience, impacts on goals (mobility, air quality, energy conservation), and an overall evaluation of 54 specific actions, based on the 376 sources listed in the appendix.

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OVERVIEW

This document is the first volume of a four-volume report covering the results of INTERPLAN Corporation's study "Joint Strategies for Urban Transportation, Air Quality and Energy Conservation" (Contract N00140-74-C-6026). The study was occasioned by the fact that the problems of mobility in cities, the quality of urban air, and transportation-related energy consumption have all come to the fore as major issues of national concern. Today's urban mobility, based on the private automobile, has been attained at the expense of excessive air pollution and the consumption of alarmingly large proportions of the nation's petroleum resources. When traffic congestion restricts urban mobility, unacceptable economic and social losses result as well as additional amounts of air pollution and gasoline consumption. Additionally, the present shortage and future natural limitations in petroleum supply portend the eventual end of urban mobility based on vehicles dependent on gasoline propulsion. Thus, all three issues are irrevocably connected in a kind of chain reaction relationship initiated by the overwhelming orientation of urban travel to the private, gasoline-powered automobile.

One by one, government agencies have been formed to direct federal action on each of these issues: the Urban Mass Transportation Administration, the Environmental Protection Agency,.and most recently the Federal Energy Administration. The administrative independence of these agencies, however, does not obscure the interdependence of the problems created by traffic congestion, air pollution, and petroleum shortages. Thus, it was felt that the goals of UMTA, FEA, and EPA—to improve urban mobility, assure an adequate supply of energy, and better the quality of urban air—should be viewed as complementary. For, from this perspective, the three agencies could accomplish more acting jointly on mutual problems than they would separately.

To investigate this thesis, then, the major purposes of the study were to: (1) identify all principal strategies and actions which impact on each of the agencies' transportation-related goals, (2) systematically elucidate the interrelationships among them, and (3) devise a way of isolating those groups of strategies and actions whose total impacts would be synergistically enhanced if implemented jointly. This volume represents the culmination of the study effort to attain these objectives.

STRUCTURAL FRAMEWORK OF THE STUDY

Early in the study's work it was recognized that a very large number of strategies and actions aimed at solving aspects of the transportation-related problems of the three agencies were currently in various stages of implementation—ranging from the purely speculative through experimental demonstrations to enacted pieces of legislation or operational equipments and/or techniques. However, in order to clarify and facilitate the comprehensive examination of each and the systematic consideration of all possible interrelationships it was first necessary to structure all the potentially viable strategies and actions in such a way as to provide a framework for the subsequent analysis. The final structure devised is presented in Table A (page vii).

In Table A an attempt has been made to organize each major action identified in the course of work under the strategy to which it principally contributes and, in turn, to place each strategy under one of the following offsetting phenomena where it will have its primary impact:

1. Improved alternatives to private auto travel
2. Improved vehicular flow
3. Reduced urban auto use
4. Reduced urban travel demand
5. Reduced vehicular emission of air pollutants
6. Reduced vehicular petroleum consumption.

These six phenomena are considered to represent those broad counter-trends which may feasibly emerge to offset the increasingly severe problems of urban mobility, air quality and transportation-related energy consumption. As shown in Table A the first four phenomena are perceived to impact primarily on the UMTA goal to improve urban mobility, the fifth on the EPA goal to improve urban air quality, and the sixth on the FEA goal to conserve petroleum resources. For ease in reference, the phenomena, strategies, and actions are denoted in Table A by a system of numerical notations: phenomena by a whole number (e.g., 1.0); strategies by two digits separated by a period (1.1, 1.2, etc.); and actions by three digits separated by periods (1.1.1, 1.1.2, etc.). The structural relationships among strategies, phenomena and goals are illustrated in Figure A.

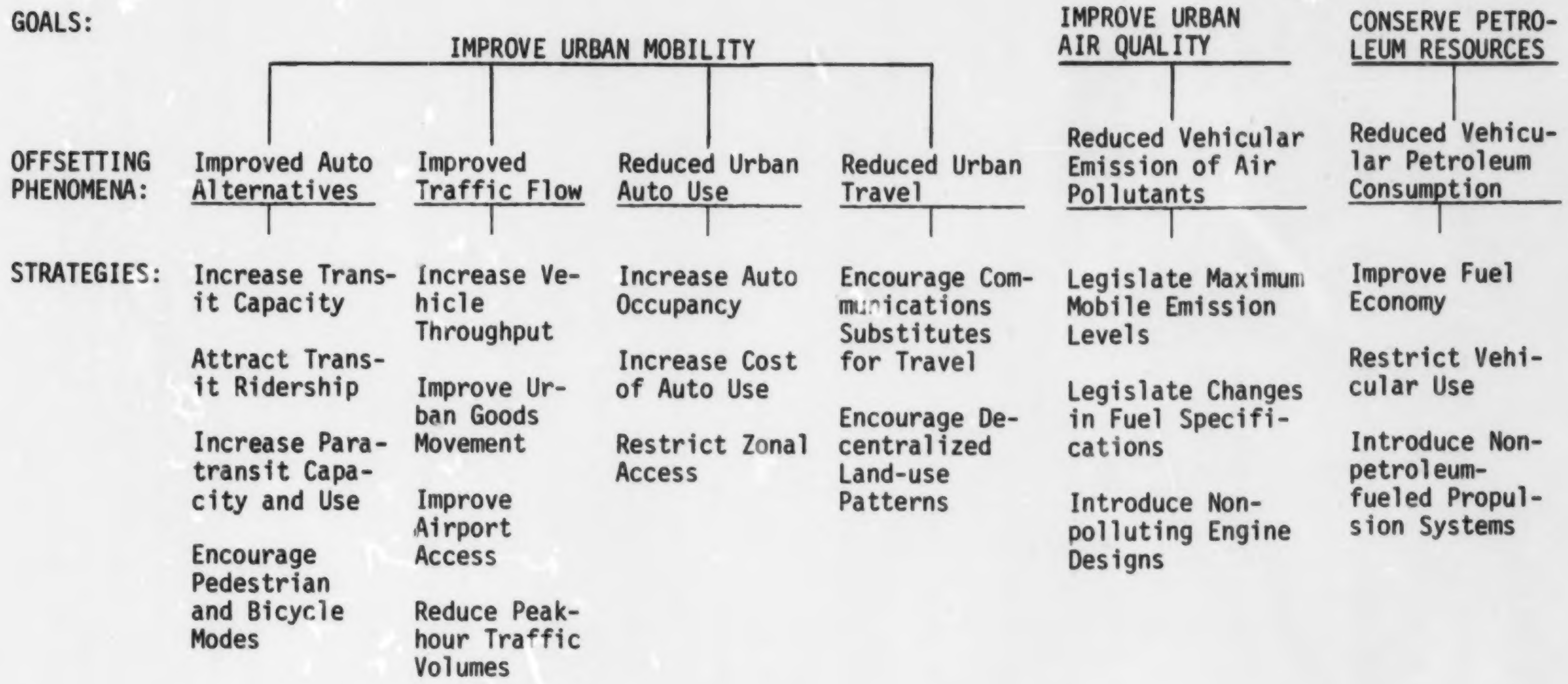
GOALS:
IMPROVE URBAN MOBILITY
IMPROVE URBAN AIR QUALITY
CONSERVE PETROLEUM RESOURCES
OFFSETTING PHENOMENA:
Improved Auto Alternatives
Improved Traffic Flow
Reduced Urban Auto Use
Reduced Urban Travel
Reduced Vehicular Emission of Air Pollutants
Reduced Vehicular Petroleum Consumption
STRATEGIES:
Increase Transit Capacity
Attract Transit Ridership
Increase Paratransit Capacity and Use
Encourage Pedestrian and Bicycle Modes
Increase Vehicle Throughput
Improve Urban Goods Movement
Improve Airport Access
Reduce Peakhour Traffic Volumes
Increase Auto Occupancy
Increase Cost of Auto Use
Restrict Zonal Access
Encourage Communications Substitutes for Travel
Encourage Decentralized Land-use Patterns
Legislate Maximum Mobile Emission Levels
Legislate Changes in Fuel Specifications
Introduce Nonpolluting Engine Designs
Improve Fuel Economy
Restrict Vehicular Use
Introduce Nonpetroleum-fueled Propulsion Systems

Figure A. Relationships among strategies, offsetting phenomena, and goals for urban transportation, air quality, and energy conservation.

FORMAT AND CONTENTS OF THIS VOLUME

Volume 1 is organized into two parts: Part I, "Formulation of Synergistic Action Programs" and Part II, "Review and Evaluation of Strategies and Actions."

In Part I the basic relationships among strategies and actions which were uncovered in the course of work are first summarized in a matrix display. Next, each action and strategy is ranked to assess the relative impact of each on the six offsetting phenomena in the near- and longer-term in order to isolate those near-term, high impact actions around which synergistic joint action programs might be constructed. Finally, such a program is formulated, illustrating how the methodology which had been developed in the course of the study could be applied to the selection of joint agency action programs.

Part II comprises the principal information database on strategies and actions required in the course of the study and the primary input to the Part I formulation of a recommended joint action program. The 376 source references utilized in the database are listed in Appendix A, located at the end of this volume. Part II is organized into six sections, each corresponding to one of the six offsetting phenomena in the structure shown in Table A. Within each section strategies are formatted as separate units, and the discussion and evaluation presented sequentially in the order shown in Table A. Each strategy commences on a new page to facilitate the insertion of new material as it appears, should the material be stored in a loose-leaf binder. The classified numbering system has also been retained to permit the insertion (or deletion) of actions without necessitating a renumbering of the entire list. The product, therefore, is offered not only as a comprehensive commentary on the current status of thought on these crucial problems, but also as a possible vehicle for maintaining currency of fact and opinion on these matters as they evolve.

The evaluation of individual strategies and actions in Part II of this volume proceeded by answering the following questions for each:

1. What has been the experience to date in this area; what is its present status, and what level of implementation has been projected?
2. What is its estimated potential for directly or indirectly improving urban mobility and/or reducing air pollution and energy use through participation in one or more offsetting phenomena?
3. What is the overall evaluation of the impact of the strategy or action—taking into account its advantages and drawbacks, possible levels of implementation, and the consequences which will accrue if it is not implemented?

Quantitative measures were cited to support the evaluation, where these existed, including estimated costs relevant to the user, to the supplying industry, and to the governmental agencies affected. In cases where the evidence located was contradictory or based on different assumptions, a tabular form was used to display the differences for easy reference. Other tables documenting operating experience or other evidence were also prepared where important, as in the case of para-transit and busways.

Table A. Structural framework of goals, offsetting phenomena, strategies, and actions.*

IMPROVE URBAN MOBILITY

1.0 Improved alternatives to private auto travel
    1.1 Increase transit capacity
        1.1.1 Provide capital subsidies
        1.1.2 Provide operating subsidies
        1.1.3 Remove supply restrictions
    1.2 Attract transit ridership
        1.2.1 Improve transit service
        1.2.2 Reduce fares and promote transit
        1.2.3 Implement transit integration
        1.2.4 Improve passenger security
    1.3 Increase para-transit capacity and use
        1.3.1 Provide implementation guidance
        1.3.2 Provide capital and operating subsidies
        1.3.3 Eliminate regulatory and labor restrictions
    1.4 Encourage pedestrian and bicycle modes
        1.4.1 Provide pedestrian facilities
        1.4.2 Provide bicycle facilities

---

*The phenomena, strategies, and actions are listed under each of the three goals according to the following structure:

X.0 Phenomenon
    X.1 Strategy
        X.1.1 Action

Table A. (continued)

- 2.0 Improved vehicular flow
    - 2.1 Increase vehicle throughput
        - 2.1.1 Extend and improve roadways
        - 2.1.2 Initiate traffic control improvements
        - 2.1.3 Utilize ramp metering
        - 2.1.4 Dedicate lanes for transit and carpool use
    - 2.2 Improve urban goods movement
        - 2.2.1 Consolidate routes and terminals
        - 2.2.2 Separate goods and people movements
        - 2.2.3 Combine passenger and freight movements
    - 2.3 Improve airport access
        - 2.3.1 Improve public transport to airports
        - 2.3.2 Increase short-haul intercity rail alternatives
    - 2.4 Reduce peak-hour traffic volumes
        - 2.4.1 Reschedule work hours
        - 2.4.2 Shorten work week
- 3.0 Reduced urban auto use
    - 3.1 Increase auto occupancy
        - 3.1.1 Encourage carpooling
        - 3.1.2 Initiate van and buspools
    - 3.2 Increase cost of auto use
        - 3.2.1 Implement road pricing techniques
        - 3.2.2 Manipulate parking costs
        - 3.2.3 Increase fuel costs
    - 3.3 Restrict zonal access
        - 3.3.1 Institute restricted or vehicle-free zones
        - 3.3.2 Limit parking spaces
- 4.0 Reduced urban travel demand
    - 4.1 Encourage communications substitutes for travel
        - 4.1.1 Increase use of existing communications facilities
        - 4.1.2 Develop neighborhood work centers
        - 4.1.3 Install home communications centers
    - 4.2 Encourage decentralized land use patterns
        - 4.2.1 Develop new towns
        - 4.2.2 Foster suburban employment opportunities
        - 4.2.3 Increase CBD residential facilities
        - 4.2.4 Disperse economic activity to smaller urban areas

Table A. (continued)

IMPROVE URBAN AIR QUALITY

5.0 Reduced vehicular emission of air pollutants
  - 5.1 Legislate maximum mobile emission levels
    - 5.1.1 Certify new vehicles
    - 5.1.2 Require in-use vehicle retrofit
    - 5.1.3 Require inspection and maintenance
  - 5.2 Legislate fuel specification changes
  - 5.3 Introduce non-polluting petroleum-based engine designs
    - 5.3.1 Improve conventional spark ignition engines
    - 5.3.2 Introduce alternative spark ignition engines
    - 5.3.3 Introduce novel combustion concepts

CONSERVE PETROLEUM RESOURCES

6.0 Reduced vehicular petroleum consumption
  - 6.1 Improve fuel economy
    - 6.1.1 Reduce vehicular size and weight
    - 6.1.2 Reduce or eliminate emission control fuel penalties
    - 6.1.3 Improve engine propulsion efficiency
    - 6.1.4 Restrict maximum speeds
    - 6.1.5 Educate car owners to optimize fuel use
    - 6.1.6 Legislate mandatory maintenance inspection
  - 6.2 Restrict vehicular use
    - 6.2.1 Legislate mandatory carpooling
    - 6.2.2 Restrict or ration fuel supplies
  - 6.3 Introduce novel, non-petroleum-based, vehicular propulsion systems
    - 6.3.1 Convert to alternative fuels
    - 6.3.2 Increase R&D and produce electric cars

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PART I

FORMULATION OF SYNERGISTIC ACTION PROGRAMS

FORMULATION OF SYNERGISTIC ACTION PROGRAMS

In INTERPLAN's view, formulation of action programs that will impact simultaneously and favorably on UMTA, EPA, and FEA goals requires careful consideration of: (1) the complementarity of the contemplated actions and (2) the magnitude of the impact each can have. It is clearly recognized that the results of these considerations will differ depending on the planning environment. National policymakers, for instance, may view the institution of dedicated lanes for transit and carpool use as a vital requirement for increasing both transit ridership and capacity. In a local environment, however, where only two-lane roadways exist, this action may not be feasible and initiation of alternatives such as bus turnouts and preferential traffic controls may be sufficiently effective to favorably alter the modal split.

In the context of the above caveat, for purposes of this study INTERPLAN first approached the problem of formulating synergistic action packages by considering the interrelationships among all actions listed in Table A (page vii) as the nature of these relationships emerged from the review and evaluation of existing information on them, documented in Part II of this volume. Then, based on this information as well as the results of other investigations and analyses published in Volumes 2-4 of this study, each action, strategy, and phenomenon was ranked to indicate INTERPLAN's judgment of its relative impact in the near- and longer-term. Finally, the four highest impact strategies (short-term) were selected as "priority" strategies around which a recommended joint action program was constructed. The results of each of these steps is described below.

INTERRELATIONSHIPS AMONG STRATEGIES AND ACTIONS

Fifty-four separate actions are listed in Table A; a total of 1431 possible interaction pairs ([(54×54)-54]÷2). In the course of the analysis each of these interactions was considered and a judgment made on the predominating kind of relationship which exists.* A knowledge of the nature of these interactions is considered important because, although it might be possible to compose an action package by combining all strategies which contribute to the same goals, some of the strategies and/or their subsidiary actions may be alternatives rather than being mutually complementary. For example, rescheduling work hours and carpooling are a potentially conflicting pair. Both contribute to lessening congestion, but carpools formed when all employees work the same hours may be broken up if a staggered hour plan is put into effect.

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*It is recognized that numerous additional interactions exist between the several possible ways each action can be implemented and, further, between the different activities which may comprise a single "action". These additional possible interactions were outside the scope of the study to examine systematically, but the most obvious are discussed in the body of Part II.

The results of this exercise are documented in Figure 1. In an effort to present a manageably sized display, when all actions under a strategy bore the same relationship to an action or all the actions located under another strategy, the results were displayed at the strategy level only. Thus, the Figure 1 matrix shows only 34 strategies and actions or 561 interactions ([(34×34)-34]÷2).

In the analysis four basic kinds of relationships were considered:

1. A pair is complementary and/or reinforcing (C)
2. A tradeoff is implied with members of the pair representing alternatives (T)
3. The pair does not interact and, hence is neither complementary nor conflicting (-)
4. There is a complementary, but dependent relationship within the pair. The letters (P) and (Q) are used in Figure 1 to denote this dependent kind of complementary relationship—one member is a prerequisite to the other, as in the case of increasing transit capacity and attracting transit ridership.

Statistically, the following breakdown of kinds of relationships among pairs can be observed, with 12 considered uncertain (U):

P: 13
Q: 5
C: 146
T: 35
(-): 350
U: 12

This breakdown shows that independent strategies and actions are the most numerous, comprising about 65 percent of the total. Thus, most of the strategies and actions listed in Table A can either be included in joint action programs or be pursued on their own merit without deleterious reciprocating effects. About 25 percent, however, are reinforcing and, hence, should receive special interagency attention because of their potential synergism. Six percent of the interactions are tradeoffs, implying that a decision is required before one or the other or both are included in the same action program. Only 3 percent bear a dependent relationship where both must be implemented in order to achieve the desired

Figure 1. Strategy/action interrelationships.

Notes:

P: Strategy X is a prerequisite to
directly complementary relations

Q: Strategy Y is a prerequisite to

C: Strategies X and Y are directly
reinforcing.

T: Strategies X and Y are tradeoff
alternative) strategies.

-: Strategies X and Y are not direc
complementary nor conflicting).

U: Strategy relation uncertain; cou
Identifies area of policy confli

"Strategy Y" "Strategy X"	1.1 Increase transit capacity	1.2 Attract transit ridership	1.3 Increase para-transit capacity and use	1.4 Encourage pedestrian and bicycle modes	2.1.1 Extend and improve roadways	2.1.2,3 Traffic control improve. & ramp metering	2.1.4 Dedicate lanes for transit and carpool use	2.2.1,2 Goods consol. & goods/people separation	2.2.3 Combine passenger and freight movements	2.3.1 Improve public transport to airports	2.3.2 Increase short-haul intercity rail	2.4.1 Reschedule work hours	2.4.2 Shorten work week	3.1 Increase auto occupancy	3.2.1,2 Implement road pricing & parking costs	3.2.3 Increase fuel costs	3.3 Restrict zonal access	4.1 Substitute communications for travel	4.2 Decentralize economic activity	5.1.1 Certify new vehicles	5.1.2 Require in-use vehicle retrofit	5.1.3 Require inspection and maintenance	5.2 Legislate fuel specification changes	5.3 Introduce clean petroleum-based engines	6.1.1 Reduce vehicular size and weight	6.1.2 Reduce emission control fuel penalties	6.1.3 Improve engine propulsion efficiency
1.1 Increase transit capacity	☒																										
1.2 Attract transit ridership	P	☒																									
1.3 Increase para-transit capacity and use	C	C	☒																								
1.4 Encourage pedestrian and bicycle modes	-	C	C	☒																							
2.1.1 Extend and improve roadways	T	T	T	T	☒																						
2.1.2,3 Traffic control improve. & ramp metering	-	-	-	C	T	☒																					
2.1.4 Dedicate lanes for transit and carpool use	C	C	C	-	T	C	☒																				
2.2.1,2 Goods consol. & goods/people separation	-	-	-	-	-	C	-	☒																			
2.2.3 Combine passenger and freight movements	C	-	C	-	-	-	C	-	☒																		
2.3.1 Improve public transport to airports	C	C	C	-	T	-	C	-	C	☒																	
2.3.2 Increase short-haul intercity rail	-	C	C	-	T	-	-	-	-	C	☒																
2.4.1 Reschedule work hours	P	U	C	-	T	-	-	-	-	-	-	☒															
2.4.2 Shorten work week	-	U	C	-	-	-	-	-	-	-	-	C	☒														
3.1 Increase auto occupancy	-	-	C	-	T	-	C	-	-	-	-	T	T	☒													
3.2.1,2 Implement road pricing & parking costs	P	C	P	C	T	Q	-	-	-	-	-	-	-	C	☒												
3.2.3 Increase fuel costs	P	C	P	C	T	Q	-	-	-	-	-	-	-	C	-	☒											
3.3 Restrict zonal access	P	C	P	C	-	Q	C	C	C	-	-	-	-	C	C	-	☒										
4.1 Substitute communications for travel	U	U	C	C	T	-	U	-	-	T	T	C	-	-	-	C	-	☒									
4.2 Decentralize economic activity	U	U	C	C	U	-	U	-	-	-	C	-	-	T	-	-	-	P	☒								
5.1.1 Certify new vehicles	C	-	C	C	-	C	C	-	-	-	-	-	-	C	-	-	C	-	-	☒							
5.1.2 Require in-use vehicle retrofit	C	-	C	C	-	C	C	-	-	-	-	-	-	C	-	-	C	-	-	C	☒						
5.1.3 Require inspection and maintenance	C	-	C	C	-	C	C	-	-	-	-	-	-	C	C	-	C	-	-	C	C	☒					
5.2 Legislate fuel specification changes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C	-	-	-	Q	Q	-	☒				
5.3 Introduce clean petroleum-based engines	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C	-	-	C	☒			
6.1.1 Reduce vehicular size and weight	-	C	C	-	C	C	-	-	-	-	-	-	-	-	C	C	-	-	-	C	-	C	-	-	☒		
6.1.2 Reduce emission control fuel penalties	-	-	-	-	C	C	-	-	-	-	-	-	-	-	-	C	-	-	-	T	T	T	T	U	-	☒	
6.1.3 Improve engine propulsion efficiency	-	T	C	-	C	C	-	-	-	-	-	-	-	-	-	C	-	-	-	T	T	-	T	U	C	C	☒
6.1.4 Restrict maximum auto speeds	-	C	-	-	-	C	-	-	-	-	-	-	-	-	-	C	-	-	-	C	C	-	-	-	-	-	-
6.1.5 Educate car owners to optimize fuel use	-	C	C	C	-	-	-	-	-	-	-	-	-	C	-	C	-	C	-	C	C	-	-	-	C	-	C
6.1.6 Legislate mandatory maintenance inspection	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C	C	-	-	-	C	C	C	T	T	C	-	C
6.2.1 Legislate mandatory carpooling	-	C	C	-	-	-	-	-	-	-	-	T	T	P	-	C	-	-	-	-	-	-	-	-	-	-	-
6.2.2 Restrict or ration fuel supplies	P	C	P	C	T	-	-	-	-	-	P	-	-	C	-	C	-	C	C	T	T	-	-	-	C	C	C
6.3.1 Convert to non-petroleum fuels	-	-	-	-	C	-	-	-	-	-	-	-	-	-	-	C	-	-	-	-	-	-	C	C	U	C	-
6.3.2 Increase R&D and produce electric cars	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C	-	C	C	-	-	-	C	C	C	C	-

a

Figure 1. Strategy/action interrelationships.

Notes:

P: Strategy X is a prerequisite to Strategy Y; implies directly complementary relationship.

Q: Strategy Y is a prerequisite to Strategy X.

C: Strategies X and Y are directly complementary or reinforcing.

T: Strategies X and Y are tradeoff (conflicting or alternative) strategies.

-: Strategies X and Y are not directly related (neither complementary nor conflicting).

U: Strategy relation uncertain; could be C or T. Identifies area of policy conflict.

"Strategy X"	1.1 Increase transit capacity	1.2 Attract transit ridership	1.3 Increase para-transit capacity and use	1.4 Encourage pedestrian and bicycle modes	2.1.1 Extend and improve roadways	2.1.2,3 Traffic control improve. & ramp metering	2.1.4 Dedicate lanes for transit and carpool use	2.2.1,2 Goods consol. & goods/people separation	2.2.3 Combine passenger and freight movements	2.3.1 Improve public transport to airports	2.3.2 Increase short-haul intercity rail	2.4.1 Reschedule work hours	2.4.2 Shorten work week	3.1 Increase auto occupancy	3.2.1,2 Implement road pricing & parking costs	3.2.3 Increase fuel costs	3.3 Restrict zonal access	4.1 Substitute communications for travel	4.2 Decentralize economic activity	5.1.1 Certify new vehicles	5.1.2 Require in-use vehicle retrofit	5.1.3 Require inspection and maintenance	5.2 Legislate fuel specification changes	5.3 Introduce clean petroleum-based engines	6.1.1 Reduce vehicular size and weight	6.1.2 Reduce emission control fuel penalties	6.1.3 Improve engine propulsion efficiency	6.1.4 Restrict maximum auto speeds	6.1.5 Educate car owners to optimize fuel use	6.1.6 Legislate mandatory maintenance inspection	6.2.1 Legislate mandatory carpooling	6.2.2 Restrict or ration fuel supplies	6.3.1 Convert to non-petroleum fuels.	6.3.2 Increase R&D and produce electric cars
city	☒																																	
ship	P	☒																																
capacity and use	C	C	☒																															
and bicycle modes	-	C	C	☒																														
adways	T	T	T	T	☒																													
rove. & ramp metering	-	-	-	C	T	☒																												
ansit and carpool use	C	C	C	-	T	C	☒																											
ds/people separation	-	-	-	-	-	C	-	☒																										
freight movements	C	-	C	-	-	-	C	-	☒																									
ort to airports	C	C	C	-	T	-	C	-	C	☒																								
tercity rail	-	C	C	-	T	-	-	-	-	C	☒																							
	P	U	C	-	T	-	-	-	-	-	-	☒																						
	-	U	C	-	-	-	-	-	-	-	-	C	☒																					
cy	-	-	C	-	T	-	C	-	-	-	-	T	T	☒																				
ing & parking costs	P	C	P	C	T	Q	-	-	-	-	-	-	-	C	☒																			
	P	C	P	C	T	Q	-	-	-	-	-	-	-	C	-	☒																		
	P	C	P	C	-	Q	C	C	C	-	-	-	-	C	C	-	☒																	
ions for travel	U	U	C	C	T	-	U	-	-	T	T	C	-	-	-	C	-	☒																
activity	U	U	C	C	U	-	U	-	-	-	C	-	-	T	-	-	-	P	☒															
	C	-	C	C	-	C	C	-	-	-	-	-	-	C	-	-	C	-	-	☒														
retrofit	C	-	C	C	-	C	C	-	-	-	-	-	-	C	-	-	C	-	-	C	☒													
maintenance	C	-	C	C	-	C	C	-	-	-	-	-	-	C	C	-	C	-	-	C	C	☒												
ication changes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C	-	-	-	Q	Q	-	☒											
leum-based engines	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C	-	-	C	☒										
and weight	-	C	C	-	C	C	-	-	-	-	-	-	-	-	C	C	-	-	-	C	-	C	-	-	☒									
l fuel penalties	-	-	-	-	C	C	-	-	-	-	-	-	-	-	-	C	-	-	-	T	T	T	T	U	-	☒								
sion efficiency	-	T	C	-	C	C	-	-	-	-	-	-	-	-	-	C	-	-	-	T	T	-	T	U	C	C	☒							
speeds	-	C	-	-	-	C	-	-	-	-	-	-	-	-	-	C	-	-	-	C	C	-	-	-	-	-	-	☒						
optimize fuel use	-	C	C	C	-	-	-	-	-	-	-	-	-	C	-	C	-	C	-	C	C	-	-	-	C	-	C	C	☒					
aintenance inspection	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C	C	-	-	-	C	C	C	T	T	C	-	C	-	C	☒				
rpooling	-	C	C	-	-	-	-	-	-	-	-	T	T	P	-	C	-	-	-	-	-	-	-	-	-	-	-	-	C	-	☒			
el supplies	P	C	P	C	T	-	-	-	-	-	P	-	-	C	-	C	-	C	C	T	T	-	-	-	C	C	C	C	C	C	C	☒		
um fuels	-	-	-	-	C	-	-	-	-	-	-	-	-	-	-	C	-	-	-	-	-	-	C	C	U	C	-	-	-	-	-	C	☒	
ce electric cars	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	C	-	C	C	-	-	-	C	C	C	C	-	-	-	-	-	C	T	☒

result. In about 2 percent of the cases the outcome of the interaction was considered to be uncertain.

It should be clearly understood that this statistical breakdown indicates only the kinds of relationships which exist among pairs of strategies and/or actions that may affect their implementation and potential synergism. It should not be taken as an indication of the degree of mutual impact the actions and strategies may have on agency goals. This aspect of the analysis is described separately in the ensuing text.

It is not possible within the study constraints to discuss or document the rationale behind all the judgments on the kinds of interrelationships among strategy and/or action pairs shown in Figure 1. Although each was basically formulated from the evaluation of actions presented in Part II, many decisions were strongly influenced by the results of other aspects of the study recorded in Volumes 2-4 and, of course, by the outcome of INTERPLAN's other transportation-related studies. The group of tradeoffs, however, although few in number potentially represent policy conflicts which must be resolved before clearly formulated action programs can be described. They are, therefore, briefly discussed below.

Tradeoff Implications

The strategy or action pairs denoted by (T) in Figure 1 are considered to be alternatives or to represent an implicit or explicit conflict, if implemented simultaneously. The following six important groups of tradeoff pairs can be observed:

1. The action of extending and improving roadways which, by increasing vehicle throughput contributes to the improvement of urban mobility, also encourages the increased use of the private auto. Hence, this action implicitly conflicts with all the strategies and actions listed under phenomenon 1.0, improved alternatives to private auto travel. For example, the Lindenwold rapid transit line in Philadelphia could be extended beyond its present terminal point to serve more commuters coming from further afield in New Jersey. Most of the existing basic infrastructure (rights of way and track) for such an extension are available. This is an alternative (a tradeoff) to the strategy of constructing new highways in New Jersey (often paralleling the existing track-line) and/or increasing the capacity of existing roadways, in order to facilitate commuting to Philadelphia.

   Most of the other actions listed under the strategy of increasing vehicle throughput and the remaining strategies and actions located

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under phenomenon 2.0, improved vehicular flow, represent attempts to improve vehicular flow within the existing roadway capacity. Hence, the action of extending and improving roadways is an alternative to these strategies and actions. For similar reasons the extension of roadways also detracts from the accomplishment of actions to increase auto occupancy and from the intention behind increasing the cost of auto use, substitution of communications for travel, and the restriction or rationing of fuel supplies.

While acknowledging that these tradeoffs exist, it is apparent that even under the most optimistic assumptions on the effectiveness and success of the alternate strategies and actions, certain extensions and improvements to urban roadways (in addition to maintenance) will have to be made to insure future urban mobility. The real problem, of course, addressed in this study and generally well-recognized, is how to determine the appropriate balance or the preferred mix of modes which will most effectively satisfy the future need for urban travel, in the light of the constraints imposed by air pollution and energy considerations. As suggested in Volume 2, Section 3 of this report, this balance is likely to differ greatly among cities and, hence, can be realistically projected only in the environment of specific local conditions.

2. The long-range strategy of substituting communications for travel represents an alternative not only to the above-mentioned extension and improvement of roadways, but also to improvements in transit access to airports (and to commercial air travel), to increases in short-haul intercity ground transportation and, implicitly, to the combination of passenger and freight movements. As the Figure 1 results show, the relationship of the communications substitution strategy to urban transit is less clear; it largely depends on patterns of future urban growth and the comparative cost of expanding transit and telecommunications services. A similar observation applies to the long-term strategy to decentralize or relocate economic activity, since the patterns of urban and regional growth will strongly influence the roles of public transit and roadways in providing mobility in future urban environments.

3. Improvements in engine propulsion efficiency will tend to conflict with attracting transit ridership as will the reduction of vehicular size and weight and removeal of emission control fuel penalties—in proportion to the extent to which fuel efficiency is improved by these actions. In general, the improvement in fuel efficiency is in conflict with or provides alternatives to:
   - Certification of new vehicles
   - In-use vehicle retrofit
   - Mandatory inspection and maintenance
   - Need for non-leaded fuels.

   The long-range potential conflict between more fuel-efficient and "cleaner" engines is uncertain. Some foreign manufacturers (e.g., Honda) have already demonstrated that these goals are attainable simultaneously. With the advent of electric or hydrogen-powered engines, however, "cleanness" ceases to be a problem.

4. Actions to encourage car and buspooling and to legally impose carpooling reduces, to a certain extent, the need to extend roadways. More importantly, they may conflict with attempts to reschedule work hours and shorten the work week unless car and buspooling requirements are specifically considered in implementation of these latter actions aimed at reducing peak-hour traffic volumes. For similar reasons the decentralization or relocation of economic activity may also conflict with efficient car and buspooling actions.

5. Rationing of gasoline (or marked increase in its price) also, to the extent that auto usage is reduced, reduces the need to extend roadways. It may also obviate the need for certification of vehicles and in-use retrofit of emission control devices, since traffic is likely to decrease. Depending on how severe the supply limitations are, it is also conceivable that ambient air quality standards could be met by gas rationing alone with no further reduction in vehicle emissions.

6. The long-range tradeoff between electric and other non-petroleum (probably hydrogen) propulsion concepts can only be resolved as a result of intensive RD&D. The outcome is not likely to be known until early 1980 at the earliest, and it is possible that eventually both modes of propulsion will coexist, electric cars being more suitable for certain uses, and hydrogen-propelled ones for other ones.

Utilization of the Interrelationship Matrix in Formulating Joint Action Programs

Use of the Figure 1 matrix (either containing INTERPLAN's judgment or those deemed by the reader to be more appropriate to his special circumstances) has been found to be an effective means of systematically examining all actions which might be appropriate to include in a joint action program and in planning safeguards against those which might mitigate the effectiveness of the intended program. The following procedure was used in the course of this study.

1. Select the principal strategies or actions which will serve as a core for the program. In INTERPLAN's use of the matrix, described below, "priority" strategies were selected on the basis of relative impact rankings. However, for purposes of this example, action 2.4.2, shorten the work week, will be considered as the action of prime interest.

2. Locate this action in the "Y" column (shaded in the Figure 1 matrix) and read off all interactions beneath this horizontal row with strategies and actions listed in the "X" column. The following relationships are noted:
   - Attract transit ridership (U)
   - Increase para-transit capacity and use (C)
   - Reschedule work hours (C)

3. Upon reaching the end of the row (denoted by a blocked-out square) relocate the action of prime interest (i.e., 2.4.2) in the "X" column and read off all interactions beside this vertical row with stategies and actions listed in the "Y" column. The following relationships are noted:
   - Legislate mandatory carpooling (T)
   - Increase auto occupancy (T)

Evaluation of the results indicates that parallel efforts to increase paratransit capacity and use and to reschedule work hours should complement the action to shorten the work week. Efforts to attract transit ridership, however, may conflict or reinforce, depending on the way in which increasing transit ridership is undertaken, and as discussed previously, shortening the work week may interfere with car and buspooling efforts.

IMPACT RANKING OF ACTIONS AND STRATEGIES

In order to form a broad background for the subsequent detailed ranking of actions and strategies, key areas where the greatest degree of interagency cooperation might be expected were first isolated. Although other alternatives were tested it was concluded that the six basic offsetting phenomena comprised the best expressions of probable areas of mutual agency interest. Based primarily on the information contained in Part II of this volume, the direction of the impact of each of the phenomena on the three agencies' transportation-related goals was perceived as shown in Table 1.

Almost all of the symbols in Table 1 might be qualified by a contradictory aspect of one or more of the subsidiary strategies or actions. These qualifiers can be observed in Figure 1 and are discussed in some detail in Part II. The purpose of Table 1, however, is to focus attention at the outset on those key areas where it appears likely that interagency cooperation could be engendered. The results show that fostering many of the strategies under the first four phenomena should be of interest to all three agencies. The fifth phenomenon, reduced vehicular emission of air pollutants, appears to run counter to the goals of both UMTA and FEA, based on the strategies and actions currently being implemented or postulated. Aspects of the sixth phenomenon, reduced vehicular petroleum consumption, are of mutual interest to all agencies, but most of the positive correlations fall principally under EPA and FEA goals and so are outside of the scope of this study.

Table 1. Basic direction of phenomenon impacts on agency goals.

PHENOMENA/PARAMETERS		GOALS		
		Increase Mobility	Improve Air Quality	Conserve Petroleum Resources
1.0	Improved Alternatives to Private Auto Travel			
	Increase transit, para-transit capacity and use (PMT/hr,PMT/VMT)	+	+	+
2.0	Improved Vehicular Flow			
	Increase average peak-hour speed (mph); decrease travel time (min.)	+	±[a]	±[b]
3.0	Reduced Urban Auto Use			
	Reduce VMT	I	+	+
4.0	Reduced Urban Travel Demand			
	Reduce urban PMT	+	+	+
5.0	Reduced Vehicular Emission of Air Pollutants			
	Reduce g/mi. emitted	-	+	-
6.0	Reduced Vehicular Petroleum Consumption			
	Restrict consumption (bbl/year)	-	+	+
	Increase vehicular efficiency (VMT/gal)	+	+	+
	Introduce non-petroleum consuming vehicles	I	+	+

NOTES: [a](-), CO, HC; (+), NO_x

[b](-), above 30 mph; (+), below 30 mph.

KEY:
(+), positive impact on goal
(-), negative impact on goal
(I), depends on implementation choice and interpretation; could be + or - .

The results shown in Table 1 represent INTERPLAN's attempt to broadly qualify the impacts which offsetting phenomena are likely to have on transportation-related agency goals. However, in order to select the priority strategies around which a recommended joint action program could be constructed it was necessary to assess the magnitudes of likely impacts, i.e., to quantify or rank them. The approach consisted of first ranking the magnitude of impact each action might have on its related strategy; then the impact of each strategy on the pertinent phenomenon was judged; and finally the phenomenon-goal impacts were ranked. Each of these iterations was accomplished by considering first the short-term impact (1975-85) and then the longer-term impacts (1980-2000).

Table 2 presents the results of assessing the impact of actions on strategies and the impact of strategies on offsetting phenomena, viewed within the context of the principal goal under which each is listed. For example, the provision of transit capital subsidies (action 1.1.1) is judged to have the highest possible significance to increasing transit capacity (strategy 1.1) in the near-term and a lesser, but still highly significant impact in the longer term. The impact of increasing transit capacity (strategy 1.1) in turn, was judged to be of medium-low importance in the near term to the phenomenon of improving alternatives to private auto travel (1.0), but to be of high significance in the longer term. This latter judgment takes cognizance of the fact that time will be required to supply additional transit capacity, as discussed in some detail in Volume 2. The judgments summarized in Table 2 also include an assessment of the feasibility of implementing each action and strategy. For example, the strategy to restrict vehicular use (6.2) is judged to be of low significance to reducing petroleum consumption, since the cited actions are unlikely to be enforceable in our society, either in the near or long term, except in the instance of a national emergency.

Table 3 presents a similar quantified assessment of the impact of offsetting phenomena on the transportation-related goals of the three principal agencies. The ranking of strategy impacts on phenomena is repeated here from Table 2 for continuity and shown under the most relevant goal, since these ranks also comprise an assessment of the strategies' impact on the goal to which it appears most closely associated. However, in view of the sizeable potential impact of reducing urban travel demand (phenomenon 4.0) on improving urban air quality, an additional impact assessment was made of the strategy-goal ranks for strategies 4.1 and 4.2.

Table 2. Near- and long-term action and strategy impacts.

		Impact Rank*
	IMPROVE URBAN MOBILITY	
1.0	Improved alternatives to private auto travel	
1.1	Increase transit capacity	4/8
1.1.1	Provide capital subsidies	10/8
1.1.2	Provide operating subsidies	10/6
1.1.3	Remove supply restrictions	4/9
1.2	Attract transit ridership	7/8
1.2.1	Improve transit service	8/7
1.2.2	Reduce fares and promote transit	9/6
1.2.3	Implement transit integration	10/10
1.2.4	Improve passenger security	9/7
1.3	Increase para-transit capacity and use	10/8
1.3.1	Provide implementation guidance	5/2
1.3.2	Provide capital and operating subsidies	6/4
1.3.3	Eliminate regulatory and labor restrictions	10/10
1.4	Encourage pedestrian and bicycle modes	3/5
1.4.1	Provide pedestrian facilities	5/6
1.4.2	Provide bicycle facilities	2/2
2.0	Improved vehicular flow	
2.1	Increase vehicle throughput	6/8
2.1.1	Extend and improve roadways	9/9
2.1.2	Initiate traffic control improvements	4/3
2.1.3	Utilize ramp metering	
2.1.4	Dedicate lanes for transit and carpool use	9/10
2.2	Improve urban goods movement	3/6
2.2.1	Consolidate routes and terminals	6/6
2.2.2	Separate goods and people movements	5/7
2.2.3	Combine passenger and freight movements	6/5
2.3	Improve airport access	4/6
2.3.1	Improve public transport to airports	8/9
2.3.2	Increase short-haul intercity rail alternatives	7/8
2.4	Reduce peak-hour traffic volumes	9/9
2.4.1	Reschedule work hours	7/6
2.4.2	Shorten work week	3/4

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*Key: 0-3, no significance, or very low significance.
4-6, medium to low importance; e.g., of local significance only.
7-8, high significance on a national scale.
9-10, highest possible significance from a national viewpoint.
The leftmost rank applies to the 1975-85 period; the rightmost, to the period after 1980-85.

Table 2. (continued)

		Impact Rank
3.0	Reduced urban auto use	
3.1	Increase auto occupancy	8/6
3.1.1	Encourage carpooling	9/7
3.1.2	Initiate van and buspools	4/6
3.2	Increase cost of auto use	1/4
3.2.1	Implement road pricing techniques	5/6
3.2.2	Manipulate parking costs	5/7
3.2.3	Increase fuel costs	9/?
3.3	Restrict zonal access	3/5
3.3.1	Institute restricted or vehicle-free zones	3/5
3.3.2	Limit parking spaces	4/4
4.0	Reduced urban travel demand	
4.1	Encourage communications substitutes for travel	2/6
4.1.1	Increase use of existing communications facilities	8/10
4.1.2	Develop neighborhood work centers	5/5
4.1.3	Install home communications centers	6/6
4.2	Encourage decentralized land-use patterns	2/5
4.2.1	Develop new towns	3/5
4.2.2	Foster suburban employment opportunities	3/6
4.2.3	Increase CBD residential facilities	2/4
4.2.4	Disperse economic activity to smaller urban areas	2/3
	IMPROVE URBAN AIR QUALITY	
5.0	Reduced vehicular emission of air pollutants	
5.1	Legislate maximum mobile emission levels	10/10
5.1.1	Certify new vehicles	10/10
5.1.2	Require in-use vehicle retrofit	6/0
5.1.3	Require inspection and maintenance	7/7
5.2	Legislate fuel specification changes	7/5
5.3	Introduce non-polluting petroleum-based engine designs	10/10
5.3.1	Improve conventional spark ignition engines	5/1
5.3.2	Introduce alternative spark ignition engines	8/10
5.3.3	Introduce novel combustion concepts	7/8

Table 2. (continued)

		Impact Rank
	CONSERVE PETROLEUM RESOURCES	
6.0	Reduced vehicular petroleum consumption	
6.1	Improve fuel economy	10/10
6.1.1	Reduce vehicular size and weight	10/10
6.1.2	Reduce or eliminate emission control fuel penalties	6/1
6.1.3	Improve engine propulsion efficiency	8/5
6.1.4	Restrict maximum speeds	2/1
6.1.5	Educate car owners to optimize fuel use	3/5
6.1.6	Legislate mandatory maintenance inspection	2/4
6.2	Restrict vehicular use	2/2
6.2.1	Legislate mandatory carpooling	3/2
6.2.2	Restrict or ration fuel supplies	5/?
6.3	Introduce novel, non-petroleum-based, vehicular propulsion systems	6/?
6.3.1	Convert to alternative fuels	1/2
6.3.2	Increase R&D and produce electric cars	0/5

It is recognized that even though these ranking exercises were based on the comprehensive literature search documented in Part II and on INTERPLAN's own extensive analyses of transportation-related issues, ultimately the assigned ranks represent the judgment of the team. This judgment is naturally subject to INTERPLAN's interpretation of the facts and its viewpoint on future events, both of which may differ from the reader's, who may wish to superimpose his own judgments for comparison.

Relative Significance of Strategies and Actions

Within the constraints of the study, it is not possible to justify or describe the rationale behind each of the impact rankings shown in Tables 2 and 3. However, it is felt that some insight into the general approach used may be gained by a brief phenomenon-by-phenomenon discussion of some of the implications which are implicit in these judgments. In each instance when an action, strategy, or phenomenon is mentioned the ranking assigned to it by INTERPLAN is given in parentheses.

Table 3. Near- and long-term impacts of strategies and phenomena on goals.

OFFSETTING PHENOMENA AND STRATEGIES	GOALS		
	Improve Urban Mobility	Improve Urban Air Quality	Conserve Petroleum Resources
1.0 Improved alternatives to private auto travel	5/8	2/3	2/4
1.1 Increase transit capacity	4/8		
1.2 Attract transit ridership	7/8		
1.3 Increase para-transit capacity and use	10/8		
1.4 Encourage pedestrian and bicycle modes	3/5		
2.0 Improved vehicular flow	9/7	2/1	1/1
2.1 Increase vehicle throughput	6/8		
2.2 Improve urban goods movement	3/6		
2.3 Improve airport access	4/6		
2.4 Reduce peak-hour traffic volumes	9/9		
3.0 Reduced urban auto use	4/5	3/4	2/3
3.1 Increase auto occupancy	8/6		
3.2 Increase cost of auto use	1/4		
3.3 Restrict zonal access	3/5		
4.0 Reduced urban travel demand	2/5	5/7	2/4
4.1 Encourage communications substitutes for travel	2/6	1/3	
4.2 Encourage decentralized land-use patterns	2/5	6/8	
5.0 Reduced vehicular emission of air pollutants	sl.neg.*	10/10	dec.neg.*
5.1 Legislate maximum mobile emission levels		10/10	
5.2 Legislate fuel specification changes		7/5	
5.3 Introduce non-polluting petroleum-based engine designs		10/10	
6.0 Reduced vehicular petroleum consumption	?/?	3/5	6/10
6.1 Improve fuel economy			10/10
6.2 Restrict vehicular use			2/2
6.3 Introduce novel, non-petroleum-based, vehicular propulsion systems			6/?

*slightly negative; decreasingly negative

KEY: 0-3, no significance, or very low significance.
4-6, medium to low importance; e.g., of local significance only.
7-8, high significance on a national scale.
9-10, highest possible significance from a national viewpoint.

The leftmost rank applies to the 1975-85 period; the rightmost, to the period after 1980-85.

IMPROVED ALTERNATIVES TO PRIVATE AUTO TRAVEL (5/8). The encouragement of this phenomenon is currently the prime responsibility and major interest of UMTA with some 90 percent of the UMTA budget being devoted to its strategies and actions. The moderate short-term rank assigned by INTERPLAN to this phenomenon reflects the fact that the measurable impact of these efforts, so far, has been slight.

For example, regarding the strategies to increase transit capacity (4/8) and attract transit ridership (7/8), transit capacity has remained virtually stable during the last 10 years, and transit ridership increased only marginally during the 1973-74 winter fuel shortages. New wage settlements, however, have increased the 1974 annual deficit of the industry close to $1 billion, clouding further the future outlook. It is for these reasons that such high impact ranks are assigned to the actions to provide capital subsidies (10/8) and operating subsidies (10/6) to transit. In INTERPLAN's view, in addition to these actions one of the most important options available to UMTA in these efforts and one which requires little time and capital is to encourage transit integration (10/10).

The complementary strategy to increase para-transit capacity and use (10/8) is assigned a high impact rank especially in the near term, since it can be fostered more quickly and at less (public) cost than transit and will provide an equally viable alternative to private auto travel in many locations. Provision for para-transit subsidies (6/4) is judged to have a significant local impact on the introduction of new services and on services which already exist or are planned in 75 cities of all sizes. Elimination of regulatory and labor restrictions (10/10), however, is viewed to have the highest short- and long-term impact on the successful execution of this strategy.

Encouragement of pedestrian and bicycle modes (3/5) thus far has been minimal. Although this strategy may cause significant improvements in urban mobility in certain CBD areas, its low rank reflects INTERPLAN's opinion on its relatively minor importance as an alternative to private auto travel.

IMPROVED VEHICULAR FLOW (9/7). This phenomenon is assigned the highest short-term rank, since the problem of urban traffic congestion is considered to be the major current obstacle to attaining urban mobility. The strategy to reduce peak-hour traffic volumes (9/9), in turn, is considered to have the highest potential impact on achieving improved vehicular flow, assuming appropriate attention is given to avoiding conflicts with other actions in its implementation.

The strategy to increase vehicle throughput (6/8) naturally will impact significantly on improving vehicular flow; however, as discussed previously, prime attention must be devoted to the tradeoffs among the actions listed under this strategy to insure that the emphasis given to each results in the optimum mix of modes which will best satisfy the future demand for urban mobility. For instance, the action to extend and improve roadways (9/9) and to dedicate lanes for transit and carpools (9/10) are each assigned exceptionally high impact ranks. This ranking, however, does not connote that equal emphasis should be placed on them. Rather, the intention is to denote that their impact on increasing vehicle throughput—at the same level of implementation effort—will be greater than, say, equivalent efforts to initiate traffic control improvements including ramp metering (4/3).

REDUCED URBAN AUTO USE (4/5). The low impact rank assigned to this phenomenon reflects INTERPLAN's opinion on (1) its significance to the improvement of urban mobility relative to, say, improving alternatives to private auto travel and (2) the fact that all strategies and actions contributing to this phenomenon, by themselves, restrict personal freedom of travel choice, both with respect to means and location and, hence, conceptually restrict mobility.

Bearing in mind this balance among the relative impacts of the phenomena on the UMTA goal of urban mobility, the strategy to increase auto occupancy (8/6), implemented mainly via the action to encourage carpooling (9/7), is judged to have the highest impact on reducing urban auto use. The short-term importance of this action to attainment of short-term FEA goals also cannot be overemphasized. It will be the main means of combating the anticipated fuel crises of 1975-76 and 1977-78 in view of the fact that neither transit nor even para-transit will be ready by that time with the needed additional capacity.

Initiating van and buspools (4/6) is also an important action within this strategy, and measurable results can be expected in 2 or 3 years if energetic organizational efforts are initiated by UMTA now. Special lanes for these vehicles, as well as preferential treatment at freeway ramps, are naturally important complementary actions.

The strategy of increasing the cost of auto use (1/4) was ranked low in the short range, first because it is inflationary and secondly, because most of the actions required to implement it are either cumbersome to introduce and maintain, or will be very unpopular with the public. The only exception is the action of increasing fuel costs—possibly drastically. While its negative effects (especially on the poor) cannot be ignored, it would serve as a potent continuous reminder to the public of the long-range world fuel shortage. In the short range, the result would be a decrease in traffic and those who stay on the road will face less congestion. It goes without saying that drastic increases in fuel prices require as prerequisites more and better transit, para-transit, bikeways, and walkways. Expansion of carpooling and buspooling would be important complementary actions.

REDUCED URBAN TRAVEL DEMAND (2/5). The low short-range rank given to this phenomenon reflects the fact that the two strategies which promote it are both of a long-range nature. Neither substitution of telecommunications for travel (2/6) nor decentralization of land-use patterns (2/5) will happen, to any significant degree, before 1980. The chances of effective substitution of communications for travel in the 1990s and later are much better. However, both strategies, jointly, will have a significant positive impact on air quality and fuel conservation.

REDUCED VEHICULAR EMISSIONS OF AIR POLLUTANTS (10/10). Since vehicular emissions have been singled out as the principal cause of urban air pollution, this phenomenon is given the rank of highest possible significance in the near- and longer-term, due to its unquestioned impact on the attainment of the transportation-related EPA goal to improve urban air quality.

The principal strategy utilized thus far has been to legislate maximum mobile emission levels (10/10) and, as indicated by its rank, it has been and will continue to be highly effective in reducing the vehicular emission of air pollutants. Unfortunately, EPA actions, implemented mainly through the certification of new vehicles (10/10) (necessitating the installation of air pollution control devices), have had negative effects on both UMTA and FEA goals. For example, decreases in fuel efficiency in 1968-74 model automobiles resulting from pollution control devices have been of the order of 10 to 30 percent (depending on the vehicle and/or the data source cited).

On the more positive side, the above strategy has been marginally effective in encouraging some manufacturers to introduce non-polluting petroleum-based designs (10/10), e.g., Honda and Mazda. A significant effort to implement this strategy, in INTERPLAN's view, would have as highly significant an impact on improving urban air quality in the near- and longer-term, as the currently implemented actions. Such a strategy would also remove the existing negative impacts on UMTA and FEA goals.

In the middle and longer time frame UMTA's efforts to improve alternatives to private auto travel will impact favorably on EPA goals. For example, UMTA R&D programs to develop a "clean taxi," to initiate production of the modern, largely non-polluting Transbus, and to revive electric rail systems—light, rapid and commuter—can eventually (by 1990) contribute to the diversion of a large percentage of auto VMT from urban roadways. As shown in Volume 2 of this report, the maximum conceivable diversion of auto VMT to transit would be equivalent to reducing vehicle emissions and gasoline consumption in 1990 by approximately 30 percent over the non-diversion case. The capital cost of achieving this goal, in terms of procuring the necessary transit equipment, however, would be on the order of $120 billion; thus its immediate effect would be also inflationary.

REDUCED VEHICULAR PETROLEUM CONSUMPTION (10/10). Since FEA (and its predecessors) did not participate directly in the conduct of this study, the resources which INTERPLAN could devote to analyzing the problem of conservation of transportation-related petroleum resources were limited. The attempt to address these aspects of EPA/UMTA strategies was further impeded by the lack of personal contacts at FEA and the consequent lack of guidance on the priority of problems. However, acknowledging that these deficiencies have impaired the analysis, INTERPLAN concluded that the relative impacts of the three strategies contributing to the conservation of transportation-related petroleum resources were as follows:

- Improve fuel economy (10/10)
- Restrict vehicular use (2/2)
- Introduce novel non-petroleum-based propulsion systems (6/high).

Among the actions within the first strategy, the highest rank was assigned to reduction of vehicular size and weight (10/10), followed by improvement of engine propulsion efficiency (8/5), and reduction or elimination of emission control fuel penalties (6/1). Restriction of maximum auto speeds, education of car owners, and mandatory maintenance inspection were also evaluated as useful, but of lesser importance.

The strategy of restricting vehicle use (2/2) can be achieved either by restricting or rationing of fuel supplies or by legislating mandatory carpooling, both actions being politically difficult to implement. If neither of these actions is implementable, the complementary actions of improving transit and para-transit, encouragement of car and buspooling, and increasing fuel costs will attain the same results.

In the long run, the introduction of novel non-petroleum-fueled engines may bring about considerable savings in petroleum. If, in addition, uranium becomes the main fuel for both electric and hydrogen-propelled vehicles, then the United States indeed can become independent of foreign sources of oil to power public and private vehicles. The present estimated R&D budget of Project Independence is $10 billion and its implementation will call for expenditures on the order of hundreds of billions in the 1980s, 1990s, and 2000s. Urban mobility will clearly benefit from those funds invested in non-petroleum-based propulsion systems. While highly inflationary in itself, this program would relieve the U.S. of the more difficult problem of "imported" inflation which has resulted from buying oil at OPEC cartel prices.

Present efforts to conserve petroleum have had a mixed effect on the nation's economy, although they have been largely complementary to attaining the goal of urban mobility; for example, they encourage the use of transit and para-transit where these modes are available. Reduction of vehicle size and weight and postponement of vehicle emission regulations also have had a positive effect on mobility by reducing the cost of travel.

However, the benefits gained by purchasers of the 2 million small foreign cars imported annually* have been counteracted at the national level by an unacceptably high imbalance in trade.

While the impact on the FEA goal of the strategies and actions listed under the EPA goal is almost exclusively negative, the converse is not true. All of the strategies and actions listed under this phenomenon, with the exception of the elimination of emission controls, have positive impacts on urban air quality, the strategy of introducing novel, non-petroleum-based propulsion systems perhaps having the highest potential impact.

SUGGESTED JOINT ACTION PROGRAMS

Selection of Priority Strategies

While Tables 1-3 indicate the direction and relative magnitude of action/strategy/phenomenon impacts on goals and Figure 1 shows the kind of relationships which exist between action/strategy pairs, it was necessary to combine these evaluations in order to isolate the most significant and yet most synergistic strategies and actions for potential interagency sponsorship.

From Table 3 it was observed that near-term ranks of 7-10** had been assigned to the following four high priority strategies whose phenomena also had a positive impact on all three agency goals:

- Attract transit ridership (1.2)
- Increase para-transit capacity and use (1.3)
- Reduce peak-hour traffic volumes (2.4)
- Increase auto occupancy (3.1)

Formulation of The Programs

Having isolated the above four strategies as the ones having the greatest near-term mutual significance to the three agencies' goals, the kinds of relationships their actions bear to other actions was then traced through the Figure 1 matrix. Table 4 summarizes these results. Lead actions denote the

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*Weighing on the order of 1600 pounds and achieving two to three times better mileage (mpg) than their American counterparts.

**7-8, high significance on a national scale; 9-10 highest possible significance.

Table 4. Priority strategies and related strategies and act

PRIORITY STRATEGIES	REDUCE PEAK HOUR TRAFFIC VOLUMES		INCREASE AUTO OCCUPANCY	INCREASE PARA-TRA CAPACITY AND US
LEAD ACTIONS	Reschedule work hours	Shorten work week	Encourage carpooling Initiate van and buspools	Provide implementati ance Provide capital and subsidies Eliminate market and restrictions
FIRST LEVEL INTERACTIONS	Shorten work week (C) Increase para-transit capacity and use (C) Increase auto occupancy (T) Attract transit ridership (U)	Reschedule work hours (C) Increase para-transit capacity and use (C) Increase auto occupancy (T) Attract transit ridership (U)	Shorten work week (T); reschedule work hours (T) Increase para-transit capacity and use (C)	Shorten work week (C schedule work hours Increase auto occupa Attract transit rider
SECOND LEVEL INTERACTIONS	Legislate carpooling (T) Extend & improve roadways (T) Substitute communications for travel (C) Increase transit capacity (P)	Legislate carpooling (T)	Legislate carpooling (P) Extend & improve roadways (T) Decentralize economic activity (T) Educate users to save fuel (C) Implement road pricing techniques (C) Increase fuel costs (C) Restrict zonal access (C) Ration fuel (C) Manipulate parking charges (C) Dedicate transit lanes (C)	Legislate carpooling Extend & improve ro Substitute communica travel (C) Increase transit cap Decentralize economi (C) Educate users to sav Implement road prici niques (P) Increase fuel costs Restrict zonal acces Ration fuel (P) Manipulate parking c Dedicate transit la
THIRD LEVEL INTERACTIONS			Require inspection and maintenance (C) Certify new vehicles (C) Require vehicle retrofit (C)	Require inspection tenance (C) Certify new vehicles Require vehicle retr Encourage pedestrian cycle modes (C) Improve transit to Reduce vehicle size (C) Improve engine effic
FOURTH LEVEL INTERACTIONS				Separate goods and movements (C)

Table 4. Priority strategies and related strategies and actions.

IC VOLUMES	INCREASE AUTO OCCUPANCY	INCREASE PARA-TRANSIT CAPACITY AND USE	ATTRACT TRANSIT RIDERSHIP
ten work week	Encourage carpooling Initiate van and buspools	Provide implementation guidance Provide capital and operating subsidies Eliminate market and labor restrictions	Improve transit service Reduce fares & promote transit Implement transit integration Improve passenger security
hedule work hours (C) ease para-transit capacity use (C) ease auto occupancy (T) act transit ridership (U)	Shorten work week (T); reschedule work hours (T) Increase para-transit capacity and use (C)	Shorten work week (C); reschedule work hours (C) Increase auto occupancy (C) Attract transit ridership (C)	Shorten work week (U); reschedule work hours (U) Increase para-transit capacity and use (C)
slate carpooling (T)	Legislate carpooling (P) Extend & improve roadways (T) Decentralize economic activity (T) Educate users to save fuel (C) Implement road pricing techniques (C) Increase fuel costs (C) Restrict zonal access (C) Ration fuel (C) Manipulate parking charges (C) Dedicate transit lanes (C)	Legislate carpooling (C) Extend & improve roadways (T) Substitute communications for travel (C) Increase transit capacity (C) Decentralize economic activity (C) Educate users to save fuel (C) Implement road pricing techniques (P) Increase fuel costs (P) Restrict zonal access (P) Ration fuel (P) Manipulate parking charges (P) Dedicate transit lanes (C)	Legislate carpooling (C) Extend & improve roadways (T) Substitute communications for travel (U) Increase transit capacity (P) Decentralize economic activity (U) Educate users to save fuel (C) Implement road pricing techniques (C) Increase fuel costs (C) Restrict zonal access (C) Ration fuel (C) Manipulate parking charges (C) Dedicate transit lanes (C)
	Require inspection and maintenance (C) Certify new vehicles (C) Require vehicle retrofit (C)	Require inspection and maintenance (C) Certify new vehicles (C) Require vehicle retrofit (C) Encourage pedestrian and bicycle modes (C) Improve transit to airports(C) Reduce vehicle size & weight (C) Improve engine efficiency (C)	Encourage pedestrian and bicycle modes (C) Improve transit to airports (C) Reduce vehicle size & weight (C) Improve engine efficiency (T)
		Separate goods and people movements (C)	

set of actions which contribute directly to the priority strategies, i.e., the actions listed under these strategies in Table A. First-level interactions show the relationships among lead actions and strategies. Second-level interactions are the collection of actions from strategies other than the priority strategies which interact with actions in three or more priority strategies; third-level interactions impinge on actions in two priority strategies; fourth-level on one.

Thus, the strategies and actions presented in Table 4 represent INTERPLAN's best judgment as to the most effective group of complementary strategies and actions which should be considered in the formation of a high-impact, interagency action program, inlcuding those which may be in conflict with them.

The most comprehensive program that could be constructed around the four priority strategies can be formulated, first, by examining the strategies and actions listed under the priority strategy which contains the greatest number of interactions. In Table 4 the priority strategy to increase para-transit capacity and use is selected since it contains the greatest number of interactions. Next, the "first-level interactions" listed in this column are expressed at the action level. The comprehensive list of the eleven lead actions (impact ranks shown in parentheses) then becomes:

Lead Actions

1. Provide implementation guidance to increase para-transit capacity and use (5/2)
2. Provide capital and operating subsidies to increase para-transit capacity and use (6/4)
3. Eliminate market and labor restrictions to increase para-transit capacity and use (10/10)
4. Shorten the work week to reduce peak-hour traffic volumes (3/4)
5. Reschedule work hours to reduce peak-hour traffic volumes (7/6)
6. Encourage carpooling to increase auto occupancy (9/7)
7. Initiate van and buspools to increase auto occupancy (4/6)
8. Improve transit service to attract transit ridership (8/7)
9. Reduce fares and promote transit to attract transit ridership (9/6)
10. Implement transit integration to attract transit ridership (10/10)
11. Improve passenger security to attract transit ridership (9/7).

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Then, potentially conflicting or uncertain relationships existing among these actions are analyzed by examining the first level interaction row in Table 4. The principal potential conflict noted lies in the fact that the actions to shorten the work week and reschedule work hours may interfere with car and buspooling efforts. These four actions (4-7, above) now are being undertaken principally as voluntary, local efforts involving industry, businesses, municipal authorities and private individuals. In this respect they are similar to actions 1 and 3 above, inasmuch as all require interfacing with diverse local groups. For this reason INTERPLAN feels that UMTA might well consider fostering a task effort to formulate policy guidance on the most effective ways to implement the following six lead actions jointly, for dissemination at the local level:

Local First-level Actions

1. Private implementation guidance to increase para-transit capacity and use (5/2)
2. Eliminate market and labor restrictions to increase para-transit capacity and use (10/10)
3. Shorten the work week to reduce peak-hour traffic volumes (3/4)
4. Reschedule work hours to reduce peak-hour traffic volumes (7/6)
5. Encourage carpooling to increase auto occupancy (9/7)*
6. Initiate van and buspools to increase auto occupancy (4/6)*.

As a result of the task effort, UMTA might also be in an advantageous position to undertake to coordinate these efforts at a national policy level (a "Local Joint Action Program") working closely in conjunction with FEA and EPA representatives, since these actions also impact favorably on short-term efforts to conserve transportation-related petroleum consumption and, to the extent that VMT is reduced, on reduction of air pollution. An ancillary, but important result of the task effort would be that UMTA would be in a much better position to suggest the level of capital and operating subsidies (lead action 2, p. 21) which would be most effective in promoting increased para-transit services and how these subsidies should be managed.

Having addressed the question of first-level interactions, INTERPLAN employed the same techniques with the second-level interactions shown in Table 4. The principal short-term tradeoff in this group involves the basic conflict between the extension and improvement of roadways and discouraging the use of private vehicular travel. This issue is beyond the scope of this study, except as it might be resolved through a determination of the "preferred" mix of modes, discussed in Volume 2 of this report.

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*In progress within UMTA.

Of the remaining actions listed in the second-level interation row, those which admit to short-term implementation are:

Short-term, Second-level Actions

1. Legislate carpooling
2. Increase transit capacity
3. Educate users to save fuel
4. Implement road pricing techniques
5. Increase fuel costs
6. Restrict zonal access
7. Ration fuel
8. Manipulate parking charges
9. Dedicate transit lanes.

Of the above, actions 1, 5, and 7 are essentially national issues. However, should it become necessary to legislate carpooling, unquestionably the results of the above-suggested "Local Joint Action Program" would be of fundamental importance to the efficient implementation of the legislation. Should increased fuel costs or fuel rationing come to pass, these events would reinforce the actions to increase auto occupancy and to attract transit ridership and, most importantly, would require that increased para-transit facilities be made available to provide a more efficient alternative to private vehicular travel.

With the exception of action 2 above, the remaining actions could well be included in the "Local Joint Action Program," since all involve interfaces with various local agencies and individuals. The strategy to increase transit capacity could well be included with the last four actions in the "Lead Action" list (page 21) in a program specifically designed to reach transit operators. This type of effort is already a part of UMTA's ongoing work.

Third- and fourth-level interactions impinge only on the strategies to increase auto occupancy, para-transit capacity and use, and to attract transit ridership. The requirements for inspection and maintenance, certification of new vehicles, and vehicle retrofits, all are, or would be, complementary to increasing auto occupancy and para-transit capacity and use. Of the remaining, which interact only with the strategies to increase para-transit capacity and use and to attract transit ridership, the improvement of engine efficiency is shown as a potential tradeoff to attracting transit ridership. Although a certain fraction of transit ridership may be diverted should more fuel efficient vehicles become available, the overwhelming benefits to FEA and EPA goals as well as to the overall UMTA goal to improve urban mobility far outweigh the drawback of potential transit ridership losses. Encouragement of pedestrian and bicycle modes and improvement in transit access to airports, the remaining near-term third-level actions, are both complementary to increased para-transit and transit and also require local interface. INTERPLAN therefore suggests that these actions also be included in the "Local Joint Action Program."

In summary, as a result of the study's analysis of the interrelationships among actions with impacts on UMTA, EPA, and FEA goals and the ranking of these impacts, the following high-priority, joint action programs are suggested.

Local Joint Action Program

1. Provide implementation guidance to increase para-transit capacity and use (5/2)
2. Eliminate market and labor restrictions to increase para-transit capacity and use (10/10)
3. Shorten the work week to reduce peak-hour traffic volumes (3/4)
4. Reschedule work hours to reduce peak-hour traffic volumes (7/6)
5. Encourage carpooling to increase auto occupancy (9/7)
6. Initiate van and buspools to increase auto occupancy (4/6)
7. Educate car owners to save fuel to reduce vehicle petroleum consumption (3/5)
8. Implement road-pricing techniques to increase the cost of auto use (5/6)
9. Institute vehicle-free zones and limit parking spaces to restrict zonal access (3/5)
10. Manipulate parking charges to increase the cost of auto use (5/7)
11. Dedicate transit lanes to increase vehicle throughput (9/10)
12. Encourage pedestrian and bicycle modes (3/5)
13. Improve public transport to airports to improve airport access (8/9)

Transit Joint Action Program

1. Improve transit service to attract transit ridership (8/7)
2. Reduce fares and promote transit to attract transit ridership (9/6)
3. Implement transit integration to attract transit ridership (10/10)
4. Improve passenger security to attract transit ridership (9/7)
5. Provide transit capital subsidies to increase transit capacity (10/8)
6. Provide operating subsidies to increase transit capacity (10/6)
7. Remove supply restrictions to improve transit capacity (4/9)

In conclusion, although these recommended joint action programs may or may not be deemed feasible to implement, it is felt that the methodology used in formulating them can be applied to the construction of other interagency programs around one or more core strategies or actions of high interest.

PART II

REVIEW AND EVALUATION OF STRATEGIES AND ACTIONS

SECTION 1

IMPROVED ALTERNATIVES TO PRIVATE AUTO TRAVEL (1.0)

INTRODUCTION

By the time the automobile became widely available, the alternative means of urban transportation were horseback, horse-drawn private or rented vehicles, horse-drawn trolley, bicycling, or walking. The auto and taxi replaced the first three, and the bus and electric rail modes replaced the horse-drawn trolley. As time passed, however, transit modes became less and less competitive, and by the 1970s, transit was hardly an "alternative" to the auto in terms of availability within reasonable walking distance, much less in terms of quality of service.

The auto-highway system has increased mobility in terms of connecting more places and making trips shorter, and building new roads has often succeeded in reducing overall congestion if traffic flow on both the new road and on pre-existing arterials is taken into consideration (196, pp. 75-81). Economically speaking, as long as the auto alternative can be afforded by consumers and is chosen in preference to other modes, there is no basis for reviving transit, para-transit, biking or walking as economically inferior goods. But some costs are not included in the price paid by the consumer, and even if they were, and auto users would pay them, the congestion, air pollution, energy and land use implications of the continued trend in auto use may be undesirable from a local or national policy point of view. Improvement of these modes with the goal of re-establishing them as viable alternatives to auto thus seems a valid approach to offsetting past trends. Making more alternatives available also automatically improves mobility in one sense of its definition, i.e., broadening the opportunities for personal travel.

The strategies to accomplish this end fall into two groups: those which affect the supply side of the market—increase transit and para-transit capacity, build walkways and bikeways—and those which affect the demand side—attract transit ridership. More emphasis is given to the first group because there is little or no excess capacity in the auto alternative modes; increasing capacity must precede service extensions, which in turn stimulate demand and are required to back up increases in demand due to marketing or fare policies. In other words, supply rather than demand is currently the limiting factor and requires stimulation.

This approach is the reverse of the one usually heard, that because declining ridership was historically responsible for declining capacity, ridership should be stimulated first to reduce the trend. The reason for this is that ridership has already turned the corner—beginning in October 1973, transit ridership in all city population groups has been increasing (Passenger Transport, 8/23/74*)—and the question is, can transit and para-transit operators make the new trend stick. The issue relevant to this study is, even if they do, will past trends be offset. The outcome depends on (a) the extent to which actions to increase the capacity and use of transit, para-transit, pedestrian, and bicycle facilities can attract former auto riders and drivers to these alternative modes; and (b) the extent to which, if such a shift occurs, mobility is increased and congestion, air pollution, and energy consumption decreased. Evidence for (a), the potential shift to auto alternatives, is presented in the discussions of the individual actions (1.1.1 through 1.4.2). Evidence for (b) in the case of an auto-transit shift is presented following the evaluation of transit subsidies (see pp. 1-6, 1-8, 1-12 - 1-13), since provision of subsidies is regarded as an important prerequisite to the strategies and actions directed at attracting transit riders. The impacts of a shift to para-transit and to bicycle and pedestrian modes are discussed individually, within the subsections on these modes (see pp. 1-48 - 1-52 and 1-64 - 1-65).

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*References to individual issues of the transit industry newspaper, Passenger Transport (PT) and to other newspapers and newsletters will be made in this fashion to avoid encumbering the reference list.

INCREASE TRANSIT CAPACITY (1.1)

Provide Capital and Operating Subsidies (1.1.1, 1.1.2)

EXPERIENCE. UMTA has been the federal conduit for capital subsidies to the urban mass transportation industry since the initiation of the capital grants program in 1964. It released about $3 billion between 1964 and 1974, $2.2 billion of it since 1972 (13, p. 32). Federal funds have been matched by at least a one-third local contribution, so that the minimum invested in transit capital since 1964 is $4 billion.

Industry statistics do show a turnaround in new bus equipment delivered to the industry after 1970 and a doubling of deliveries in the next three years from 1400 to 3200 vehicles a year, putting annual deliveries back up to where they had been in the early 1960s (13, p. 17). Rail vehicle deliveries, on the other hand, were lower in the '70s than in the '60s.

So far much of the bus vehicle and facilities purchasing seems to have gone to replace aging vehicles and plants and to reduce average vehicle and maintenance costs. This trend is understandable given the capital-poor status of transit over the last two decades. However, net increases in the fleet size are required before new capacity can be translated into new or expanded service. Information available from the American Transit Association indicates that the urban bus fleet continued to decline in 1973 as it has since 1955: preliminary figures indicated about 48,300 buses in the fleet in 1973 compared to 49,100 in 1972 and 56,800 in 1950 (13, p. 19). In contrast, a slow climb is observed over the last 10 years in the number of rapid rail cars, from 8,900 in 1963 to an estimated 9,700 in 1973, or about back to their 1950 level.

It can only be surmised from this data that while net increases in bus fleet size were experienced in some individual cities receiving UMTA capital grants, such was not the case in all grant cities, and in fact about 10,000 more buses must have been retired than were purchased over the 1970-1973 period in order to explain the ATA figures. This phenomenon can be expected to continue as companies reduce both average fleet age and normal bus lifespan. Boston's MBTA, for example, announced earlier this year that they hoped to decrease average fleet age from 8.3 to 5 years and normal bus lifespan from 12 years to 10 (PT, 4/5/74). Therefore while capital grant expenditures are of vital importance to rejuvenating the U.S. urban bus fleet, only a part of the funds spent can be expected to add to net capacity.

Since the UMTA Act of 1970 granted the DOT Secretary obligational authority for capital grants of $3.1 billion for 5 years, and an additional $3 billion in capital grants was included in the 1973 Federal Aid Highway Act, about $4 billion in capital grants remains to be authorized and awarded by UMTA by FY 1976. The impact of these funds is further strengthened by the Act's increasing the maximum two-thirds federal portion to a mandatory 80 percent. A follow-up six-year transit bill of $11.8 billion passed the House in August 1974; up to 40 percent of this amount could, for the first time, go to operating expenses, with the decision to be made by the recipient cities.

An extremely important new source of federal funding for urban transit systems was opened up by the provision in the 1973 Federal Aid Highway Act for the transfer of interstate highway construction funds and federal-aid urban system funds to public transit projects. Already $600 million for transit improvements has been transferred from Interstate funds in Boston (PT, 6/14/74), $51 million in Interstate funds to Philadelphia's SEPTA, $33 million from urban highways to the New York City Transit Authority, and $1.5 million in urban system highway funds to the St. Louis Bi-State Development Agency (PT, 7/12/74). There is no estimate of how much transit could receive from the state legislation mentioned above, since further voter action will be decisive, or from the Interstate transfers, since these require the withdrawal of a specific portion of an Interstate route and the subsequent approval of a transit alternative for which the federal 80 percent share could not exceed the foregone Interstate cost. As a result of new flexibility in the use of urban system funds, beginning in FY 1974 an additional $800 million per year could be used by communities for transit projects approved by the governors of their states. This legislative breakthrough at one stroke increases significantly the federal funds available for capital improvements in urban transit (PT, 8/10/73).

More than the increase in the amount of capital funds now available, the option to use federal funds for either capital or operating expenses which would obtain if the House-passed bill becomes law should serve to boost the level of bus and rail capacity and service quality, if one accepts the analysis of a 1973 Highway Research Board article by William Tye (292). Dr. Tye's analysis shows that restricting federal subsidies to capital grants "will encourage a costly over-capitalization of the industry." (p. 32). The reason for this is that the two-thirds federal share is an incentive to incur subsidized capital costs rather than unsubsidized operating expenses. "One way to achieve this is by premature replacement, which increases the capital costs of purchasing new buses but decreases the operating expense of maintaining an older fleet." (p. 34).

His recommendation is to allocate grants among states and cities as a generalized subsidy; in this way the recipients have an incentive to maximize use of the money rather than spending it inefficiently. Rather than drastically replacing their vehicles, they will have an incentive to continue using old vehicles while at the same time applying the new. This should lead to an increase in the national urban bus fleet and a consequent increase in the capacity of transit modes.

On the state and local level, most states and cities offer aid to urban mass transit systems. Most private transit companies have been bought up by public agencies which then have taken financial responsibility for providing and subsidizing service. Publicly owned systems, which in 1973 made up 18 percent of the total number of systems (up from 14 percent in 1971), carried 91 percent of revenue passengers and owned 80 percent of transit vehicles (75 percent of buses, 100 percent of rail vehicles) (13, p. 3). By 1972, 16 states had state-level DOTs with authority to set priorities for the distribution of state transportation funds, and 14 more were studying forming such an agency (56, p. 336). Many states are now providing direct subsidies for construction, operating, and planning costs, and are enacting legislation to permit establishment of transportation authorities to plan, build, and operate regional transportation systems (56, p. 338). The 1973-74 winter energy crisis spurred state action to help transit: six states (Arkansas, California, Colorado, Connecticut, Massachusetts, and Tennessee) passed legislation approving the use or special levying of various taxes (motor vehicle, sales, property, liquor, street aid) for transit operations (PT, 2/1/74).

In four representative U.S. cities*, operating and capital costs not recouped from fares are covered by state and local agencies, as shown in Table 1-1. These cities are representative of the recent trend towards greater subsidization of mass transportation facilities. That financial support has been equal to maintaining adequate service can be seen by the quick and successful response of U.S. transit systems when faced by substantial numbers of new riders during the fuel shortages of the past winter; this evidence is presented in the discussion of the strategy of attracting transit riders below.

IMPACTS ON GOALS. Capital and operating subsidies will impact directly on mobility, in the sense of increasing the opportunity for personal travel, to the extent that they increase net transit carrying capacity in terms of more frequent service (shorter headways) or new or extended routes. For each extra bus put into service, some number of travelers will find available to them a service offering a new alternative to some auto trips.

Boosting transit capacity will impact on the other two goals—air quality, and energy conservation—mainly by facilitating strategy 1.2, "Attract transit ridership", discussed below. Increases in capacity alone may be sufficient in the strictest sense of the word to increase auto alternatives, but the impact resulting from a given number of new buses depends on the use to which these buses are put. Increasing transit capacity is therefore a necessary but not sufficient condition for increasing transit ridership; it must be combined with measures to increase transit ridership (strategy 1.2).

The real issue is, if the strategies of increasing transit capacity and attracting transit ridership are combined, what effect will this have on mobility, air quality and energy use? While mobility is increased by any net addition to total transportation services, the extent to which the other two goals are served depends on the number of auto trips which are actually replaced by transit following the increase in transit capacity and service.

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*The rationale for selecting these four cities is presented in Volume 4 of this report, pp. 75-79. They were selected as being cities of mutual concern to both EPA and UMTA.

Table 1-1. Federal, state and local transit subsidies in four representative U.S. cities.

LOS ANGELES: SCRTD (1964)

State and Local Financing	Amounts received - 1973 ($millions)	
State pays 40% of operating cost (rest covered by fares) and provides local matching of funds. Authority to place property and sales tax on local ballot for construction of new systems.	**Capital**	
	Federal	$ 8.6
	State sales tax	2.9
	Total	$11.5
	Operating	
	Federal Emergency Employment Act	$ 0.4
	State sales tax	42.0
	City & Community Redevelopment Agency	0.2
	Total	$42.6

PHILADELPHIA: SEPTA (1963)

State and Local Financing	Amounts received - 1973 ($millions)	
Capital funding: 80% federal, balance split between state and local governments (city, county). Operating expenses covered by state (2/3) and local (1/3) (city and counties).	**Capital**	
	Federal	$11.9
	State capital grant	2.0
	County new bus project	0.2
	City - Model Cities and pedestrian underpass	0.2
	Total	$14.3
	Operating	
	State general funds	$25.2
	County general funds	1.5
	City general funds	11.4
	Total	$38.1

SEATTLE: Metro (1958)

State and Local Financing	Amounts received - 1973 ($millions)	
Sales tax of 0.3% for operating expenses of a Regional transit system approved by voters in Sept. 1972. Combined MTC & Seattle Transit System (STS) operations in 1973. STC (within city) Operating expenses covered by fare revenues and city general and earmarked funds. State matches local taxes one-to-one with motor vehicle excise tax funds. MTC (outside city) Private company; contracts with county with financial aid provided by communities served.	**Capital**	
	Federal	$ 0.9
	Operating	
	Federal Emergency Employment Act	$ 0.1
	State motor vehicle excise tax & business tax exemption	3.2
	Transit district (0.3% sales tax)	10.1
	Total	$13.4

Table 1-1. (continued)

BALTIMORE: MTA (1973)

State and Local Financing	Amounts received - 1973 ($millions)	
Receives state funds as agency of Maryland DOT Mass Transit Administration. Local funds from a gasoline tax.	Capital	
	Federal	$ 2.2
	State Transportation Fund	0.7
	Total	$ 2.9
	Operating	
	State Transportation Trust Fund	$ 1.8

Sources: State and Local Financing: Seattle, Ref. 136, Vol. 3, pp. 203-209. Other cities, Ref. 44 — Los Angeles, p. INS-9.01; Philadelphia, p. OOS-26.01; Baltimore, p. OOS-2.04. Amounts received in 1973: Ref. 17, pp. 3, 4, 6, 7, 11, 12, 14, 15.

Unfortunately, to INTERPLAN's knowledge, there has been no attempt to determine a predictable relationship between increases in transit capacity or service and the number of auto riders shifting to transit (cross elasticity of demand for auto and transit as a function of change in transit service). Some evidence that this relationship is direct and positive is presented in the discussion of action 1.2.1 (improve transit service); the relationship between fares and ridership has received considerable attention in the literature and is also discussed (action 1.2.2, reduce fares and promote transit). But this evidence does not always distinguish between the impacts on ridership of the several factors at work: if capacity is increased, service improved, and fares reduced while the cost of competing auto travel is increased, all these factors must be considered as interdependently responsible for any increase in ridership.*

For this reason, the evidence located by INTERPLAN on the impacts of these two strategies (increase transit capacity and attract transit ridership), summarized in Table 1-2, relates exclusively to the impacts of a switch from auto to transit, independent of the causes for the switch. All seven references abstracted in the table approach the issue by assuming some auto-transit

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*Further analysis of the relationships between these factors and ridership is an important R&D need in urban transportation economics and could be immediately undertaken with proper data, possibly from a 10-year review of the federal transit capital grants program.

Table 1-2. Documented impact of strategies and actions on offsetting phenomena: Increase Transit Capacity (1.1), Attract Transit Ridership (1.2).

PHENOMENA						COST ESTIMATES	
1.0 Improved Auto Alternatives	**2.0 Improved Vehicular Flow**	3.0 Reduced Urban Auto Use	4.0 Reduced Urban Travel Demand	5.0 Reduced Vehicular Air Pollutant Emissions	6.0 Reduced Vehicular Petroleum Consumption	**Highway, Auto**	**Rail, Bus & Para-Transit**
Reference 144a Maximum conceivable diversion to transit by 1990 of 620 billion auto PMT (modal split increases from 8 to 43%).	Certain to be considerable due to drop in VMT. No data.	Drop in 1990 urban VMT by auto and transit from 963 to 640 billion (33%).	No change in PMT or trips.	31% CO reduction (1.1 million tons/year), 28% HC reduction (120,000 tons/year), 18-30% NO_x increase (10,000 tons/year) in 1990 over no-diversion case.	30% energy savings in 1990 over no-diversion case (2.6 quadrillion Btu/year or 1.3 million bbl/day).	Increase in transit capacity would obviate need for some part of $45 billion 20-year investment in highway infrastructure; would save economy about $25 billion/year in operating and capital costs.	Annual operating + capital cost (excluding capital replacement cost) would be about $39 billion (bus: $7.3, demand-responsive minibus: $12.2, light rail: $5, and rapid rail: $14.7 billion).
Reference 136 32.7 billion transit riders by 1990.	Not mentioned.	40 million fewer commuter cars/day.	No change.	Positive impact; no data.	Not mentioned.	Not mentioned.	$126 billion to 1990: for 50,000 buses ($2.5 billion), rail vehicles, track equipment ($30 billion), over-the-water ($0.6 billion), plus $10.6 billion total annual operating cost.
Reference 3 Positive impact; no data given. Institution of an "extensive transit network" estimated to increase modal split by less than 1%.	Not mentioned.	5% fewer VMT in CBD, 1% in region with moderate investment alternative; 1.5% in region for maximum investment plan.	No change.	5% reduction of 1977 emissions in CBD, and 1% in region.	Not mentioned.	Not mentioned.	$567 million agency cost for moderate investment alternative (to 1977); $1.2 billion for state-proposed plan. User savings: $1.2 billion. Highest cost effectiveness of 7 strategies examined.

Table 1-2. (continued)

PHENOMENA						COST ESTIMATES	
1.0 Improved Auto Alternatives	2.0 Improved Vehicular Flow	3.0 Reduced Urban Auto Use	4.0 Reduced Urban Travel Demand	5.0 Reduced Vehicular Air Pollutant Emissions	6.0 Reduced Vehicular Petroleum Consumption	Highway, Auto	Rail, Bus & Para-Transit
Reference 246 20% overall ridership increase would add 1 billion annual rides. If 20% of present 34 million commuter trips switch, 6.8 million transit riders would be added in the peaks.	Not mentioned.	700 million fewer auto trips/year (at 1.5 persons/car).	No change.	Not mentioned.	500 million gals. saved (13.5 mpg and average commuter trip = 9.4 mi.).	Not mentioned.	At no additional cost, 1.5 million riders at each peak could be accommodated. To provide for 6.8 million, $1.5 billion required: $1 billion for 26,500 vehicles and $.5 billion for property, equipment.
Reference 298 12 billion trips/year in 1990, or 18% higher than base projection of about 10 billion rides. Equivalent to .75% annual increase, 1968-1990.	Positive impact on congestion; no data (p. II-91).	Positive impact on VMT; no data (p. II-91).	No change.	Positive impact; no data (p. V-32-V-35).	Indirect positive impact from reduction in congestion. No data.	Savings of 6.8% overall in urban freeway miles, ranging from 3% in 50,000 to 250,000 pop. group to 11% in over 1 million group, 4.3% overall savings in total arterial investment, including new freeways, other new arterials, and reconstruction, ranging from 1% to 6% (same two pop. groups) (Fig. II-20, p. II-74).	Not mentioned.

Table 1-2. (continued)

PHENOMENA						COST ESTIMATES	
1.0 Improved Auto Alternatives	2.0 Improved Vehicular Flow	3.0 Reduced Urban Auto Use	4.0 Reduced Urban Travel Demand	5.0 Reduced Vehicular Air Pollutant Emissions	6.0 Reduced Vehicular Petroleum Consumption	Highway, Auto	Rail, Bus & Para-Transit
Reference 328 High transit funding alternative results in more than twice as much of an increase in modal split, i.e., 45% vs 20% increase over 1968, than if highway transit funding allocation remained same as that implicit in 1972 State "needs" estimate. Peak share would increase 2½ times as much (70% vs 25%). Daily transit trips would increase by 130% rather than 90%.	More than twice as much of a decrease in peak auto speed (17% vs 7% decrease 1968-90). Slight improvement in transit peak travel times vs 5% increase with "needs" split.	Implicit reduction in VMT; data not given.	No change.	A doubling in the daily tons emitted (100% increase over 1968) is predicted for CO, HC and NO_x for both the "needs" and high transit alternative.	Not mentioned.	One-half as great an increase in urban freeways (40% increase over 1968 compared to 80% increase if highway-transit split stays same as for 1972 State "needs").	Transit to receive $135 billion 1968-1990 ($6 billion/year). Twice as much of an increase in rapid transit line-miles (400% increase over 1968 compared to 200% increase if highway-transit split stays same as 1972 State "needs").
Reference 254 Due to bus production limitations, at the most about 10% of urban auto travel could be diverted to bus by 1990, although theoretically 20% could be diverted (60% of CBD-oriented travel and 12% of non-CBD travel).	Shift to transit will mean an increase in trip time for most travelers. At present, transit takes 2-3 times longer than auto.	10% PMT would be shifted to bus. No calculation of resultant reduction in VMT.	No change.	Not mentioned.	At twice the current bus occupancy rate (25 pass./vehicle), annual energy savings would rise to nearly 2% in 1990; savings over the 1974-1990 period would amount to about 41 billion gals., or 1.3% of total transportation fuel consumed during the period.	Not mentioned.	248,000 new buses would be required; their net present value is $6.2 billion.

shift; the capacity and ridership increases and changes in congestion, air pollution, and energy use are derived directly from the initial assumption. The question of *how* to achieve this shift in an individual city is a matter of applying the actions reported on under the strategy of increasing transit ridership, recognizing that the impact of these actions on attracting auto drivers has not been empirically determined and will be difficult to predict.

An indication of the potential impact on congestion which would result from increasing transit capacity and ridership (under the assumption that the auto-transit shift will be made) was gained during INTERPLAN's Volume 2 analysis postulating an increase in urban modal split (transit and para-transit share of total travel) to 43 percent by 1990 as a result of diverting to transit and para-transit all projected increases in auto travel between 1974 and 1990.* Under the assumptions of the example, total projected 1990 PMT is the same, but the vehicle miles required to accomplish this travel are one-third lower than without the diversion. Although estimating the impact on 1990 congestion of such a reduction in 1990 VMT requires further assumptions on 1990 roadway miles and condition, clearly some substantial gain in traffic flow would be experienced by auto drivers as well as transit and para-transit vehicles.

The National Transportation Report example (328) foresees quite different results because of the assumptions on which it is based. Instead of a fivefold increase in modal split by 1990, this example assumes a 50 percent increase (70 percent during the peak), or 1/10th as much. Urban freeway miles would need to be increased half as much as if the highway-transit split stayed the same as for 1972—a 40 percent increase over 1968 freeway miles rather than an 80 percent increase. The associated impact on both traffic flow and emissions is negative rather than positive: auto speed is projected to decrease 17 percent by 1990, compared to a 7 percent decrease if the highway-transit funding allocation remains the same as implicit in the 1972 State "needs" estimate; and daily tons of CO, NO_x and HC emitted are projected to double in both cases (no change for high transit investment).

The National Transportation Report example is the most sophisticated of the conservative estimates in Table 1-2. The extreme contrast between these estimates and INTERPLAN's is a reflection of the fact that INTERPLAN deliberately looked at the "maximum conceivable diversion" to transit by 1990 in order to see if the lack of significant impacts previously reported was due to the conservative nature of the assumed diversion to transit. Where timidity had failed to reveal the scope of potential gains, boldness succeeded: reductions in vehicle miles traveled and emissions, and energy savings of about 30 percent are predicted by INTERPLAN's analysis.

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*See Reference 144a, Section 2, "Public-Private Urban Transportation Modal Mixes and Their Impact on Energy Consumption and Air Pollution Tradeoffs," pp. 212-222.

OVERALL EVALUATION. The significance of the extreme contrast between the estimated impacts of the transit strategies reviewed above is the key to these strategies' overall importance. If the policy target is to increase modal split by 10, 20 or even 50 percent, the payoff in emission reductions and barrels of oil saved is likely to be disappointing; congestion reductions will depend on the extent to which roadway construction is slowed in order to transfer funds from highway to transit modes. But if national and local policy aims at a "big leap forward" of doubling or quadrupling modal split, the gains in emission reductions and energy savings could significantly offset the trend of increasing petroleum consumption, speed the attainment of the ambient air quality standards, and reduce congestion, providing roadway growth does not stagnate.

Even more interestingly, a large part of the cost of such a major shift —in INTERPLAN's example $39 billion a year excluding capital replacement— could conceivably be recouped if the savings to the economy—$25 billion annually in auto capital and operating costs—could be tapped by fiscal or other means. These savings, added to an estimated annual savings in roadway investment of about $1 billion (one-half of $45 billion ÷ 20 years) and an undetermined sum in roadway maintenance savings, could amount to two-thirds of the total annual cost. Since this total excludes capital replacement and the remaining $15 billion a year is not an inconsiderable sum, this particular example clearly oversteps the financial constraints. A more moderate but still bold program should nevertheless be considered as a policy alternative worthy of further exploration.

Remove Supply Restrictions (1.1.3)

One important action for increasing transit capacity which the Volume 1 and Volume 2 work uncovered is the need to either spur domestic bus production or lift bus import restrictions in order to alleviate the current and future shortage of transit buses. Supply limitations constrain the effectiveness of capital subsidies (1.1.1) in two ways: (1) they place a ceiling on the annual number of buses which can be added to urban fleets, and (2) they create strong market forces encouraging suppliers to absorb new capital investment funds by raising prices. While INTERPLAN identified this problem too late to systematically investigate the structure of the bus industry and import restrictions and their underlying causes,* the analysis of a 1973 TSC report of the U.S. bus market abstracted in Table 1-2 (254, Appendix 2; see last section of table) indicates serious limitations in domestic bus production which may not be entirely due to a lack of productive capacity. A letter from a GMC spokesman cited in the report states that the U.S. single shift capacity for the production of urban transit buses is about 6,000 a year; since annual new bus deliveries as reported by the transit industry have exceeded 3,000 vehicles per year only three times since 1951, it would seem that some idle capacity already exists despite long bus delivery times. Several new manufacturers (AMC, Rohr-Flxible) have entered the field in the past few years; the 1974-75 Bus Industry Directory lists 14 smaller manufacturers besides GMC, AMC, Rohr and Mercedes-Benz of North America. MB is the only company also listed among the dozen diesel engine manufacturers (39, pp. 153, 155), six of whom also sell bus engine parts.

The same GMC spokesman is quoted in Reference 254 as saying that there are no foreign manufacturers producing equipment that conforms to U.S. specifications and legal requirements (p. A-7-7). To what extent this refers to restrictions on buying foreign vehicles or to other safety or dimensional specifications is unknown to INTERPLAN. Certainly many presumably German-manufactured MB buses are now in operation in U.S. cities (9 were just supplied to the Santa Barbara Metropolitan Transit District for minibus use); British Leyland Motors has tested a deluxe executive bus with room for 20 executives and two secretaries and facilities for typing, photocopying, dictation and social drinking in Leonia, N.J. (PT, 2/1/74); and Metro Seattle began testing the Swedish Volvo motor bus and the Swiss-made Hess trolley in March for about five months to decide if the equipment should be acquired for local use (PT 3/29/74). These facts seem to indicate that there is some opportunity for foreign vehicles in the U.S. transit market. Certainly if import restrictions did not exist and market demand exceeded domestic supply (which is inevitable if a massive shift to transit occurs), some foreign manufacturers would find it worth their while to make any minor modifications required in order to capture a portion of the U.S. bus market, as they have done in the automobile market.

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*To INTERPLAN's knowledge, no such investigation has ever been done, though the subject is of crucial importance to the future of public transit.

In any case, if bus transit ridership is to be greatly increased, domestic capacity may well be inadequate to keep up with the new demand, especially if, as claimed in March 1974 Senate testimony by a New York stock and bond company board chairman, GM sees little profit in bus manufacture and can restrict bus supply due to its monopoly power (Public Transit Report, March 31, 1974). The balance of payments consequences of lifting restrictions on urban bus imports should be weighed against the need for more buses and the possible benefits in price reductions from permitting foreign competition.

ATTRACT TRANSIT RIDERSHIP (1.2)

The two short-run and two long-run actions selected by INTERPLAN as the most effective in the experience of U.S. and European transit systems in attracting transit riders, including former auto drivers and passengers, are:

Short-run

1. Improve transit service
2. Reduce fares and market transit

Long-run

3. Implement transit integration
4. Make transit riding safer.

The short-run actions are those which in the 1973-74 American transit renaissance have been widely practiced and widely successful. The long-run actions, which have been recognized as goals by many U.S. systems, reflect the need for the strong institutional structure, region-wide physical and operational coordination of transit service, and broad acceptance of transit which are typical of European systems and which are a necessary base for effective future service improvements. These actions, supported by adequate financing (1.1.1, 1.1.2), are the keys to success in offering a viable alternative to urban auto travel. The tremendous strides made in transit service and planning since INTERPLAN's review of the industry in its 1973 report, Integration of Transit Systems, coupled with the new funding sources opened to transit within the last year, reported on above, are cause for optimism that this aim can be attained.

Improve Transit Service (1.2.1)

EXPERIENCE. Transit service improvements fall into two categories: extension and expansion of existing bus or rail service, and construction of new rail systems. The most dramatic gains in ridership are associated with new rail systems: an Arthur D. Little report on the proposed Los Angeles rail system estimates that with a conservative ridership of 1.5 million per day, 250,000 to 500,000 vehicles a day would be removed from the Los Angeles freeways (PT, 8/30/74). However this estimate is contingent on (1) an increase in the price of gasoline to 75¢ a gallon, (2) increased parking costs, and (3) continuation of the 25¢ fare. Despite equipment and labor problems,

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San Francisco's new BART system has attracted 85,000 riders a day and has consistently surpassed its daily ridership forecasts by 15 percent (30-40 percent for peak hour forecasts). A May 1973 rider survey showed that 52 percent of riders were using BART as a direct replacement to the auto (PT 4/12/74).

The long lead time required to construct rail systems (12-15 years estimated for the Los Angeles system, if approved by voters in November 1974) qualifies building rail transit as a medium- to long-term approach. Advanced systems still in the development state such as dual mode, air cushion and magnetic levitation applications (see Volume 3) will not enter the picture until 1990 or later. If the present trend continues, however, all 30 cities with 1970 populations greater than 1 million* will be building rail systems by 1980. In addition to the 7 cities with rail systems already in operation, more and more are jumping on the bandwagon, some even from the less-than-one-million population group (†): Washington, Atlanta, Baltimore, St. Louis, Minneapolis, Seattle, San Diego, Kansas City, and New Orleans are planning or building rapid transit systems; Los Angeles is seeking voter approval of a rapid rail plan; and Dayton(†), Rochester(†), Detroit, Austin(†), Pittsburgh, Miami, Buffalo, Denver, Tampa, and Portland are planning light rail systems. Only five of the 30 cities in the over 1 million group have no plans to build rail systems (Houston, Dallas, Milwaukee, Cincinnati, Indianapolis).

Attracting auto riders by short-term bus service improvements should, according to the very thorough analysis of the San Diego Clean Air Project (102, p. 22), focus on reducing headways by running buses more frequently, increasing area coverage to make more people bus-eligible, and reducing fares to zero. (The fare question is dealt with separately below as part of a joint fare/marketing action program; see. pp. 1-26). U.S. bus systems have been following this approach since the beginning in 1973 of an increase in riders as illustrated in Table 1-3. Since the table is a compilation of service improvements and associated ridership increases reported in the transit industry newspaper during the first six months of 1974, it gives only partial information, but the evidence listed is representative of what has been happening to the bus industry since the beginning of 1973. In individual cities with service improvements, ridership shows increases of 10-20 percent.

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*There are 33 SMSAs with 1970 populations over 1 million, or 30 if Anaheim and San Bernardino are grouped with Los Angeles, San Jose with San Francisco, and Patterson, N.J. with New York City.

Table 1-3. Selected evidence of transit service improvements in U.S. cities and their impacts on ridership.

City and Description of Program	Change in Ridership
FOUR CASE CITIES	
Los Angeles (Santa Ana). Orange County Transit District has begun placement of 165 benches at bus stops, each equipped with route map, printed schedule and slogan. Lease of benches will cost $19,000 a year. (1/11)*	OCTD general manager predicted benches would boost already increasing ridership.
Philadelphia. Broad Street Subway extended in 1973; extension of Reading commuter rail line will be completed this year; 144 rail cars have arrived to replace old vehicles. Extensive renovation and reconstruction is scheduled for 1974. (4/12)	Ridership is up 16% over last year (rail system).
Seattle. 1973. In Metro's first year of operations, 620 miles were added to the bus and trolley route system, an increase of 40%, a transit-only lane was developed for the a.m. peak, and the fleet was increased. (1/18; also Ref. 14)	11-15% increase in ridership over 1972.
Baltimore. More park-and-ride and express buses added by Baltimore MTA. (1/25)	
OTHER CITIES OVER 1 MILLION POPULATION	
New York. MTA, which operates the subways, buses, and commuter rail lines in the New York area, has rescued the city's transit facilities from collapse. (4/12)	Commuter rail ridership has increased about 11% over last year.
San Francisco. BART's East Bay and City lines now open, equipment availability is limiting ridership expansion. (4/12)	BART ridership was 15% higher than daily forecasts and 30-40% higher than peak forecasts. Daily ridership about 85,000 by March 1974, with peak hour riders comprising about half. July/Aug 1973 strike did not dampen trends; 90% of ridership was regained in 2 weeks.

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*Dates refer to 1974 issues of Passenger Transport (ATA weekly). Source for ridership column same except where noted.

Table 1-3. (continued)

City and Description of Program	Change in Ridership
Oakland. AC Transit adds second special senior citizens bus service to take residents of a Hayward, CA, mobile home park to a shopping area twice a week for regular fares. The first service carried residents of an Oakland retirement community to shop. (1/11)	200 people benefitted from first year's service; 900 are expected to be served under the Hayward plan.
Pittsburgh. PAT installing 130 new transit shelters for $404,000. New express bus service, parking lots, and reduced fares also part of PAT's program. (2/1)	
Dallas. Doubling of crosstown bus loop service follows expansion of same line several months' earlier. Three new park-and-ride operations had been initiated earlier. (5/31)	Following first crosstown extension, patronage nearly doubled and the line is close to self-supporting.
Atlanta, 1972. 30% increase in bus vehicle miles (5.8 million) over 2-year period, requiring 71 vehicles and resulting in 14 new lines, 16 extensions, 90 headway improvements or expansion in service periods. (Ref. 158)	Change in ridership in first year, 1.5-1.6 million revenue passengers added to base of about 41 million/yr. (4% increase); (fare reduction added another 8.2 million or 20%; see Table 7.); second year service improvements are expected to add 3-4.5 million (10%) more (demand elasticity with respect to vehicle-miles = +.3).
Cincinnati. With funds from a new city earnings tax of .3% approved by voters in Nov. 1972, bus company was able to lower the bus fare from 55¢ to 25¢, buy new buses, initiate a marketing program, and inaugurate a 10¢ downtown shuttle. A federal corridor express demonstration (the Sun Run) was taken over. (4/17)	Ridership a steady 45-50% higher than last year. Sun Run carried 50% more riders than the two regular routes serving the same area.
San Diego, 1973. 28% increase in annual bus vehicle-miles operated. (Ref. 158)	19% increase in ridership (demand elasticity of +.7 to +.8).
Miami. Dade County MTA implements charter bus-pool system for commuters with companies sharing expense with employees carried. (1/18)	
Miami. Six express bus routes have been added or expanded since January. (3/1)	Ridership increased 10% from November to January.

Table 1-3. (continued)

City and Description of Program	Change in Ridership
Portland. Tri-Met approves funds for metro-wide carpooling computer match-up to save fuel. (1/18)	
CITIES BETWEEN 500,000-1 MILLION	
Rochester. Park-and-ride route extending 40 miles into Genesee County has been jointly implemented by the Rochester-Genesee Regional Transportation Authority, a state-created public agency, and Empire Trailways Co., a private operator. The TA had developed plans; Trailways initiated the service in November 1973. Revenues in first month covered basic operating costs. (1/11)	New service attracted 1514 passengers in its first month and ridership continued to grow in December.
Rochester. Rochester-Genesee Regional Transportation Authority places 14 vandal-proof stainless steel benches in bus shelters in response from a request by local senior citizens and handicapped persons. (1/25)	
Dayton. Success of Downtown Area Short Hop (DASH) free bus service in Dayton has triggered similar service in Seattle, Duluth, Chattanooga, Birmingham, Nashville, and Akron. (2/22)	DASH ridership 6,000/week.
Syracuse. Subscription express buses are so much in demand that more buses will be needed. (3/8)	10 buses carrying 420 people (full load) now in operation.

Summary data on the four representative cities received from the ATA, shown in Table 1-4, shows a definite correlation between increased route miles and net additions to fleet and ridership, independent of fare changes. Although no industry-wide figures on service improvements are available, such improvements are probably at least partly responsible for the reversal of the historic trend in transit ridership in all city population groups, as documented for the first 5 months of 1974 in Table 1-5. The increase in ridership which began in October 1973 coincided with, and was probably catalyzed by, the onset of the 1973-74 winter gasoline shortage, but the higher levels of ridership have been maintained and slight further gains made since gasoline supplies returned to normal in April-May 1974. At the end of August, the cumulative increase in ridership for the calendar year was more than 7 percent compared to the same period in 1973 (*PT*, 9/27/74), or slightly higher than the 6.7 percent figure given in Table 1-5 for the January-May period.

Table 1-4. Change in bus route miles, fleet size, fare, and ridership for the four representative cities, 1972-1973.

	Change from 1972 to 1973 in			
City	Bus route-miles	No. buses in fleet	Fares (¢)	Ridership (%)
Los Angeles	+555	+166	0	+4.5
Philadelphia	0	-8	0	-3.9
Seattle	+620	+496	-5	+11.0
Baltimore	+217	+50	0	+5.5

SOURCE: Ref. 14

Table 1-5. Transit revenue passengers by city population groups, Jan.-May, 1974.

Population group (1970 census)	No. (millions)	Percent change from 1973
Cities		
Over 500,000	1,767	+ 5.7
rapid transit	613	+0.5
surface	1,154	+8.7
250,000-500,000	303	+ 5.2
100,000-250,000	98	+ 8.5
50,000-100,000	86	+12.8
Less than 50,000	58	+29.7
Subtotal - all cities	2,313	+6.5
Suburban	136	+10.9
Grand total	2,449	+6.7 (wt. av.)

SOURCE: Ref. 16

In Table 1-5, it is significant to note that in the largest population group, where riders most often have a choice between rail and bus, the bus traffic increased far more than rail (8.7 vs 0.5 percent) and was responsible for most of the overall increase (5.7 percent) within that size group. It is also interesting that the largest percentage increase in ridership occurred in the smallest cities—50,000 and under—so that in effect the number of new 1974 riders in these small cities was slightly higher than that in the largest size group (about 13,000 vs about 10,000 new riders). These gains are even more impressive when one considers the city-by-city listing published by the ATA for its members (15); less than 10 percent of the 100 systems listed failed to see some increase in ridership during these 6 months. These statistics make it clear that the increase in transit ridership is a nationwide urban phenomenon, not one confined to a single city group.

What little statistical evidence that is available relating ridership increase and service improvements (all work done by Michael A. Kemp at the Urban Institute: 157 and 158; see Atlanta, San Diego in Table 1-3) indicates that the overall transit demand elasticity with respect to vehicle miles operated ranges from 0.3 to 0.8—given that fare decreases were made along with the service improvements in the cases studied. Further analysis of the data would be required to learn what portion of this increase is attributable to service improvements alone and what portion of new trips would have been made by auto or were new trips (diverted vs induced travel demand).

A Charles Rivers Associates study of 1963-64 Boston data, cited in a Kemp paper (157, p. 40), is discouraging on this account: cross elasticity of demand for transit and auto were found to be very low, indicating that it would be difficult to divert auto travelers to transit by either lowering fares or improving service. It is agreed, however, that ridership is consistently more sensitive to service changes, defined in terms of ride time, than to fare changes at existing levels of service (157, p. 38). The time elasticities of demand for work (-0.7) and shopping (-0.6) trips found in the Boston study were nearly four times the fare elasticities (157, p. 41). Another analysis of 1956 Cook County (Chicago) data arrives at a time elasticity of -0.9 (157, p. 44); more recent data from the San Francisco Bay area (1969) show time elasticities ranging from -0.55 to -1.29 (157, p. 45). Kemp's collected evidence certainly argues in favor of service improvements which would shorten travel time.

An October 1973 analysis of transportation control strategies for Baltimore further shows that one minute of waiting time is perceived by riders as having the same disutility as two minutes of riding time (197, p. 25); reducing average transit waiting time by one minute by reducing vehicle headways was estimated to reduce downtown VMT by 3 percent and regional VMT by 2 percent (no transit ridership figures given). The same result was reported by the San Diego Clear Air Study (102, p. 22). The Pratt study (239, p. 151) emphasizes the necessity of introducing automation of bus scheduling to any plan of providing faster and more frequent bus service.

So, more frequent service, plus amenities at stops which would tend to reduce the disutility of waiting (benches, shelters; see Los Angeles, Pittsburgh, Rochester in Table 1-3) are also important components of a program to improve service in order to attract new riders. Such a program should also include transit company sponsorship of other transit-related actions evaluated separately in this report, such as pedestrian and bike access to transit (1.4), bus lanes and busways (2.1.3), transit airport access (2.3.1), encouraging staggered work hours (2.4.1), and carpooling and buspools (see Miami, Portland and Syracuse in Table 1-3).

IMPACTS ON GOALS.* As mentioned above (pp. 1-8, 1-12), there has been little quantitative analysis which would permit reliable prediction or forecast of the impact of service improvements on auto travel, emissions and energy use. Kemp's review of time elasticity values indicates that the gain in ridership due to, say, a 10 percent decrease in travel time is likely to range from 5 to 13 percent—*in the existing ranges of service*. But he also cites data from a subscription bus service demonstration in Peoria in 1966 as evidence that as other (non-time related) service characteristics improve, demand becomes more elastic with respect to fare (157, p. 39); this suggests that at higher levels of service, both in terms of time spent and other more difficult to quantify terms, proportionately greater ridership changes would occur than indicated by the elasticities.

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*The broader impacts of an auto-transit switch due both to increases in capacity (1.1) and to all measures to attract transit ridership (1.2.1 through 1.2.4) are discussed on pp. 1-8, 1-12 - 1-13, and summarized in Table 1-2 (pp. 1-9 - 1-11).

In any case, the elasticity analysis does not tell us what proportion of new riders attracted by service improvements were auto drivers; this proportion is likely to vary with the type of service anyway. About half of BART's ridership, as mentioned on p. 1-18, has been made up of former auto drivers, and Kemp's analysis of the Atlanta no-fare demonstration indicates that about 65 percent of new trips made had previously been made by auto (158, p. 26). These two bits of information hardly constitute conclusive evidence. No efforts have been made, as far as INTERPLAN knows, to systematically gather data on the proportion of new riders diverted from auto or to measure directly changes in traffic flow, ambient pollutant levels, or gasoline demand as a function of transit service improvements.

Scattered bits of information support the view that service improvements have some, but not much, impact on these parameters. The San Diego Clean Air Project is the most optimistic: bus system improvements costing $20 million in annualized expenditure for San Diego could reduce auto mileage by 5 percent (102, p. 38); an additional $70 million would be required to reduce mileage by another 5 percent. The Baltimore transportation control strategies analysis mentioned above (p. 1-24) estimates that a 3 percent decrease in downtown VMT and emissions would result from a one minute decrease in transit travel time; furthermore, this strategy is deemed the second most cost-effective (sum of agency and user benefits and costs is $9 million) of the six strategies evaluated, following traffic flow improvements ($45 million) (197, Table 2). A report prepared for the California Air Resources Board in 197[illegible] concludes from a review of consultants' analyses of strategies to reduce auto usage in Los Angeles that reducing transit wait, ride times, or fares would not increase transit ridership enough to accomplish a 20 percent reduction (106, p. 31). An Alan M. Voorhees evaluation of strategies to reduce energy use (6) estimates a 1 to 3 percent regional energy reduction, and a non-quantified decrease in congestion and air pollution from transit service improvements. Another multi-strategy analysis estimates that improvements in public transportation would reduce motor vehicle emissions by less than 5 percent (133, p. 11); it also reports that despite the outstanding service and ridership record of Philadelphia's Lindenwold Line, "a reduction in motor vehicle traffic directly attributable to the Lindenwold Line has not occurred, at least as reflected in available data." (133, pp. 5-28)

OVERALL EVALUATION.* The recurring theme in References 6, 102, 106, 133, and 197 is that while transit service improvements alone seem to produce very little reduction in auto mileage and consequent air pollution and energy use, a joint strategy combining bus service improvements and increased cost of auto use (strategy 3.2), and/or restricted zonal access (strategy 3.3) can produce substantial mileage reductions at a lower total cost. In the San Diego Clean Air Project, for example, a $20 million expenditure for bus improvements plus an auto mileage surcharge would result in more than a 15 percent mileage reduction; the same expenditure on buses, or a surcharge alone, would produce only a 5 percent reduction (102, p. 28). Thus improving transit service is a vital action promising substantial benefits—if included in the right package of strategies, i.e., with increasing transit capacity, increasing cost of auto use, restricting zonal access, and with the other actions to attract transit ridership discussed below.

Reduce Fares and Promote Transit (1.2.2)

Reducing transit fares and promotion of transit are discussed as a combined action partly because fare reductions are very often a major element of promotional campaigns. Both are also often combined with service improvements in such a way that their individual effects are blurred, but more work has been devoted to distinguishing the impact of fare changes than of the other actions. This is probably because fares are easier to measure than service, because more data is available, and because understanding fare impacts permits transit companies to estimate the change in their financial position to be expected from a fare change. As more data is gathered on the effects of service improvements and marketing programs, better analysis of their impacts on ridership will become possible.

EXPERIENCE. A historical study of the comparative cost of transit and auto travel shows that over the last 15 years, the cost of private transportation has decreased relative to the general cost of living and that public transportation has increased in cost over twice the amount of the decrease for private transportation (260, p. 364). Even so, in money terms it is still less expensive to ride transit than auto for those who have the choice. An ATA comparison of DOT and ATA statistics on auto and transit user costs indicates it costs about 15¢ per mile less to commute by transit than by car: the average auto commuter spends between 11¢ and 18¢ a mile to get to work, while the public transit commuter spends about 3.4¢ a mile (PT, 6/7/74).

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*An overall evaluation of the combined effectiveness of the strategies to increase transit capacity (1.1) and attract transit ridership (1.2), to which this action would contribute, is given on p. 1-13.

Estimation of the fare elasticity of transit demand, or the change in ridership due to a change in fares, has in the past focused on what happened when fares increased, because there simply were no cases of fare decreases. According to Michael Kemp's very useful summary of past empirical and theoretical work on transit demand elasticities (157), transit demand is not very elastic with respect to money price when fares are being increased: short-run direct fare elasticities are characteristically observed to lie within the range of -0.1 to -0.7. His more recent paper on the same subject finds that these results are confirmed by others' analysis of European data (158, p. 4).

The latter paper also reports on the fare decreases in Atlanta, San Diego, and Cincinnati; elasticities in these cases are on the low end of the range (-0.15 to -0.45; 158, pp. 22, 29, 30). Compared to earlier data on fare increases, this implies that more riders drop out when fares go up than are regained when fares are lowered. New data on the results of the April 1974 Los Angeles bus fare reduction (114) suggest a fare elasticity of -0.4 (+0.2/-0.5); this is far less than transit officials were hoping.

Since a fare elasticity of -1.0 represents the breakeven between gaining and losing gross revenue when fares are changed, these low figures imply that while ridership can be increased, the transit company loses some money for each new rider gained. In the Atlanta example, each new revenue passenger cost MARTA $1.00-1.25 in revenue; the figure in Cincinnati was 70¢ and in San Diego, 37¢. INTERPLAN estimates a figure of $1.10 for the Los Angeles fare decrease ($34.6 million in county subsidy to continue the reduced fare, divided by 31.4 million new passengers a year). These figures represent only the loss in revenue; they do not include the extra cost of running the service. Kemp estimates on the basis of a MARTA ridership survey that the cost in lost revenue per car journey removed from the road was about $3.

Despite these apparently paltry ridership gains and the necessity of subsidizing fare reductions, more and more transit operators are lowering fares, partly because of new sources of subsidy which have recently become available to them, and because lowering fares has been seen as a key component in successful multi-dimensional marketing effort. In the first six months of 1974, nine cities abolished or lowered fares for general riders (does not include special fares for senior citizens and other special groups), to add to the 32 cities reporting reduced fares in 1973 issues of the industry newspaper.* Some examples of combined fare and marketing programs are given in Table 1-6, which covers only the first six months of 1974. The substantial ridership increases associated with these programs (15-150 percent) are partly due to the renewal of interest in transit during the winter fuel shortage, but ridership gains have continued into the summer months.

The table also illustrates the renaissance in marketing techniques which began in 1973. Transit systems seem to vie with one another in inventing catchy slogans to attract riders to notice and take advantage of:

- discounts for off-peak, weekend, downtown, and shopping rides;
- new bus stop information signs, information booths, and ad programs;
- new transit logo and exterior bus graphics.

More innovative techniques are also being tried: a private bank in Milwaukee has offered free downtown service on London doubledeckers which they purchased and operate; newspapers are sold on buses in Syracuse; and free rides given to BankAmericard holders in Tulsa. One tiny Connecticut transit district (Valley Transit District, Derby, Connecticut) has put into effect a credit card system ("Fairtran") for bus riders, as suggested in INTERPLAN's 1973 transit integration study (136, Vol. 2, p. 269). The development of the computer-based monthly billing system, which can also generate origin and destination data, ride and price information for special agencies or customers, and time and length of ride data, was sponsored by an UMTA R&D grant (PT, 8/30/74). Pittsburgh's port authority credited a free ride offer during the morning hours of the first day after settlement of a transit strike with helping to bring post-strike ridership back to above its pre-strike level (PT, 1/11/74).

An even greater expansion of marketing programs should be seen next year as the first major UMTA project to improve transit marketing techniques begins to bear fruit. The $465,800 contract, announced in February 1974, will develop a methodology for measuring the effectiveness of a marketing program that

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*Cities reporting fare reductions in 1974 are: Nashville, Newport (KY), Akron, Baltimore, Los Angeles, Newark, Long Beach, Dayton, and New Orleans. The following cities reported fare reductions in 1973: Pittsburgh, Denver, Santa Ana, Allentown, Tucson, Indianapolis, San Diego, Cincinnati, Auburn (NY), Kansas City, Hagerstown (MD), Chicago, Syracuse, Boston, Louisville (KY), Tulsa, Atlanta, Seattle, Hartford, Chattanooga, Cleveland, St. Louis, Toledo, Philadelphia, Newport (RI), Norfolk, Dallas, Birmingham, Portland, Arlington (VA), and New York City.

Table 1-6. Evidence of transit marketing and promotion programs in U.S. cities and their impacts on ridership.

City and Description of Program	Change in Ridership
FOUR CASE CITIES	
Los Angeles. Rapid Transit District initiated Sunday Sample Day on January 20; fare reduced to 10¢ (1/18).* Program continued. (2/1)	Sunday bus ridership increased 80% but revenues were halved. (2/1) Program discontinued 6/30 (Los Angeles Times (7/1).
Los Angeles. County funds to be allocated to support reduction of fare to 25¢ during the week (Sunday fares already reduced to 10¢). (3/22)	First week of reduced fare, RTD carried 17% more riders than usual. (4/26)
Los Angeles (Orange County). Prepaid fare contracts (like group insurance) in effect for students of University of California at Irvine, employees of a shopping center, senior citizens of La Habra, and city employees of Santa Ana. (3/15)	Net patronage increases of 6% per month partially credited to innovative marketing techniques.
Seattle. Metro's school information program has visited 90 classes in 30 schools with slide shows and buses to ride. (3/31)	
Philadelphia. No programs reported.	
Baltimore. Super Sunday tickets offered for all-day ride at special fare (50¢ vs 30¢ regular fare). Promotional brochure distributed at public places and retail outlets, TV and radio advertising used, newspaper feature with route map and feature articles. (3/15)	5,000 tickets sold first Sunday, 14,000 the third (3/15). Ridership ranged 80-100% above normal. (5/17)
OTHER CITIES OVER 1 MILLION POPULATION	
New York. The half-fare Sunday transit program culture bus loops and a mid-town shoppers' grid are key elements in MTA's marketing program, begun in late 1973. (4/12)	Sunday patronage increased 34% (about 600,000 rides each Sunday) (5/31); 55,000 have taken the Culture Loop tours since their inauguration in the fall of 1973; Midtown shopper buses carry about 1,500 riders a day.

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*Dates refer to 1974 issues of Passenger Transport (ATA weekly). Source for ridership column same except where noted.

Table 1-6. (continued)

City and Description of Program	Change in Ridership
New York. Restaurants participate in MTA's "Save on Sunday" program by offering a 10% discount to holders of Sunday half-fare transit tickets. (4/26)	
Chicago. Special system-wide reduced Sunday fares offered for experimental period in March. (3/8)	44% increase in bus and rail lines on first Sunday (3/22); has ranged up to 70% (4/12).
Oakland. "Teamwork" human relations program to establish better communications between bus drivers and students. Two Oakland Raiders (football) players and a bus driver are visiting junior high schools in AC Transit service area with a 15-minute slide show about the bus system. (1/4). See also Los Angeles (Santa Ana), PT 1/11 above.	
Boston. Off-peak "dime-time" expanded. Now in effect 10 a.m.-2 p.m. during week and all day Sunday. (3/1)	Off-peak ridership increased 15%. (4/12)
Boston. First 20 new bus stop signs bearing route, schedule, and fare information are being installed in Newton suburb begin program to replace ancient signs. Massachusetts' state commissioner of public works suggests the basic graphic approach could become basis state-wide uniform information signs. (4/5)	
Boston. Payroll deduction pass program began in March. (4/26)	John Hancock Life Insurance Co. and departments of the state government are participating.
Pittsburgh. Special family ride tickets (4 for 1, Dollar a Weekend) offered permitting any family up to 4 members to ride anywhere in PAT service area over weekend. (2/22)	April weekend ridership is up up 27% over 1973; about 10,000 passes are being sold each weekend. (6/7)
Pittsburgh. Payroll deduction plan inaugurated in October 1973. (4/26)	Nine institutions now participating, with 520 customers holding permits.

Table 1-6. (continued)

City and Description of Program	Change in Ridership
St. Louis. Local bank offers a transit token for each customer transaction, and a 10-token bonus for a new account or loan. (5/17)	
Cleveland. $290,000 in advertising for transit to be provided by local media in exchange for bus card space on transit vehicle. (3/22)	
Minneapolis-St. Paul. Image of old-time autos painted on bus side panels. Story used by a national educational magazine as subject for an instructive cartoon episode for school children. (4/19)	
Dallas. Punch cards for paying bus fares are introduced. Squares are punched by driver to record cost of fare. (3/8)	
Milwaukee. Four London double-deckers will offer free downtown shuttle bus service, paid for by a local bank (purchase and operating costs). (4/26)	
Cincinnati. Southwest Ohio Regional Transit Authority staff have taught a 2-week series of classes on transit to 9th and 10th graders. SORTA hopes transit will soon be included in schools' urban living course and hopes that such instruction will help reduce vandalism. (1/11)	
San Diego. San Diego transit and 11th U.S. Naval District launch joint program to encourage naval personnel to ride bus. 78,000 maps distributed during five weeks. (3/22)	
Denver. A Chicago design firm has been awarded a $167,000 contract to develop a system of graphics for Denver transit, including signs, uniforms, bus colors, route maps, etc. (2/1)	

Table 1-6. (continued)

City and Description of Program	Change in Ridership
CITIES BETWEEN 500,000-1 MILLION	
Columbus. Local newspaper published a 24-page supplement with complete timetables for local transit routes, along with route maps and promotional material. A month-long multi-media advertising program is also underway. (3/1)	
Dayton. Reduced fares and extended hours (11:30 p.m. instead of 5:00 p.m.) go into effect for summertime special "Happy Hours" service. (6/28)	
Syracuse. Local newspapers are available for sale on buses. The bus company should make $500/month from the sales. (2/8)	
Allentown. Ride and shop program sponsored by area merchants; shoppers get a free ride home with validated ticket; stores pay fares. (1/25)	700 residents took advantage of free ride home during first week, 5,217 during first 5 weeks; merchants and transit company enthusiastic. (2/22)
Nashville. A local department store bought the bus system for one day—Easter Sunday—and offered free rides to all. (4/26)	Ridership up 150% over normal Sunday. April ridership expected to increase because of promotion.
CITIES BETWEEN 250,000-500,000	
Tulsa. BankAmericard holders allowed to ride free; fares paid by card's local bank sponsors. Other types of special identification could be used as basis for similar promotional scheme. (2/1)	2,000 BankAmericard riders in one day. Transit authority's most successful promotion.
Madison. Information booth set up on a one-day basis in different locations to answer questions, distribute schedules and maps. (2/1)	

includes market research, service planning, fare and schedule revision, and promotional activities (PT, 3/1/74). It will also conduct two 18-month demonstrations concurrently in Baltimore and Nashville, selected out of 50 cities applying as demonstration cities (PT, 8/2/74), and publish a transit marketing manual. This project should also stimulate collection of needed data on the impact of marketing programs; present lack of such data prohibits any quantification of the ridership gains or the cost effectiveness of such programs, by themselves and relative to other approaches to increasing transit ridership.

IMPACTS ON GOALS AND OVERALL EVALUATION.* With regard to the impact of fare changes alone, the missing link is again the relationship between transit and auto ridership. This relationship can be described as the cross elasticity of auto demand with respect to transit fare, which indicates to what degree people can be diverted from their cars by decreasing the transit fare. The "very uncertain estimates" of cross elasticities which Kemp cites are of the same order of magnitude as the transit fare elasticities, though somewhat lower: +0.14 (157, p. 41) and +0.21 (157, p. 43). Even if more were known about attracting auto drivers, additional data on observed traffic flows would be required to confirm the magnitude of the potential impact on congestion. Kemp remarks in connection with the Atlanta no-fare demonstration that MARTA did not make any monitoring of traffic flows to measure changes in congestion resulting from the fare reduction. INTERPLAN has seen no data of this kind for Los Angeles either, although a news story reported that nearly 90 percent of new riders attracted by the fare reduction have cars or access to one, a much higher percentage than for old riders (114).

The only theoretical analysis on VMT and fares, one made for Baltimore, estimates a 7 percent reduction in CBD VMT (197, p. 25) (see Table 1-7). More importantly, it finds this strategy to be relatively cost-effective. Costs and benefits to users and the implementing agency sum to a net gain of $12 million for Baltimore. This makes subsidy of fare reduction one of the

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*The broader impacts of an auto-transit switch due both to increases in capacity (1.1) and to all measures to attract transit ridership (1.2.1 through 1.2.4) are discussed on pp. 1-8, 1-12 - 1-13, and summarized in Table 1-2 (pp. 1-9 - 1-11). An overall evaluation of the combined effectiveness of strategies to increase transit capacity (1.1) and attract transit ridership (1.2), to which this action would contribute, is given on p. 1-13.

Table 1-7. Documented impact of strategies and actions on offsetting phenomena: Reduce Transit Fares (1.2.2)

PHENOMENA						COST ESTIMATES	
1.0 Improved Auto Alternatives	2.0 Improved Vehicular Flow	3.0 Reduced Urban Auto Use	4.0 Reduced Urban Travel Demand	5.0 Reduced Vehicular Air Pollutant Emissions	6.0 Reduced Vehicular Petroleum Consumption	Highway, Auto	Rail, Bus & Para-Transit
Reference 239, pp. 110-126. Ridership drops 0.32% for every 1% increase in fares; no data on increase in riders with decrease in fares.	Longer travel times would be faced by persons switching to transit; no evidence given.	Cross-elasticities of demand between transit and auto travel are very low or negligible.	New trips and travel may be induced by no-fare.	Will be reduced to the extent that auto switch is made; no data.	Not mentioned.	For average work trip of 10 miles, auto user paying 10¢ each way (subsidized fare) saves $670/year over driving alone, $190 over using unsubsidized transit, and $100 over joining a 3-passenger carpool; his annual commuting costs are $53.	Annual operating deficit with no fare would range from about $780 in a small (75,000) city to $4 million in a medium-sized city (300,000) and $9 million in a large city (1.3 million), with corresponding operating costs per bus mile of 77¢, 96¢, and 91¢.
Reference 158 Atlanta. Over the first year, fare reduction is estimated to have resulted in a 19% increase in revenue pass. carried. Ridership increased 0.15-.2% for each 1% drop in fare (fare elasticity = -.15 to -.2) compared to earlier estimates that ridership dropped .6% for each 1% increase in fares (p.22).	No data.	No data collected, but author estimates about 3.3 million auto trips were substituted by bus trips. Survey results show greatest diversion of new riders from auto for peak-hour commuters.	No change.	Not mentioned.	Not mentioned.	Not mentioned.	MARTA's deficits on operating account ($12 million or 22¢/pass.) and city's contribution to transit construction costs are financed by a special 1% sales and use tax in participating local jurisdictions. The MARTA bus fare was reduced from 40¢ to 15¢ in March 1972, a 60% decrease. The fare reduction cost MARTA about $10 million/year in revenue, or about $1-1.25 per revenue pass. gained, or $3/auto trip substituted.

Table 1-7. (continued)

PHENOMENA						COST ESTIMATES	
1.0 Improved Auto Alternatives	2.0 Improved Vehicular Flow	3.0 Reduced Urban Auto Use	4.0 Reduced Urban Travel Demand	5.0 Reduced Vehicular Air Pollutant Emissions	6.0 Reduced Vehicular Petroleum Consumption	Highway, Auto	Rail, Bus & Para-Transit
San Diego. 23% increase in revenue pass. in first year; fare elasticity between -0.4 and -0.45 (p. 29).	Not mentioned.	Not mentioned.	Not mentioned.	Not mentioned.	Not mentioned.	Not mentioned.	San Diego. Deficit is $7 million/year (35¢/pass.). Fare reduction from 40¢ to 25¢ cost 37¢ for each passenger gained.
Cincinnati. 32% increase in 5 months; fare elasticity, -0.38 (p. 30).	Not mentioned.	Not mentioned.	Not mentioned.	Not mentioned.	Not mentioned.	Not mentioned.	Cincinnati. Fare reductions of about 50% expected to require subsidy of about $6 million/year, or 70¢/passenger gained.
Reference 197, p. 25. Baltimore. Not given.	Not given.	1977 CBD VMT would be reduced by 7%; regional VMT by 4%.	No change.	Assumed to be reduced by the same percent as VMT.	Not mentioned.	Not mentioned.	Baltimore. Agency cost of a fare reduction from 30¢ to 15¢ would be $16 million annually, or a present cost of $156 million. Users realize $15 million of this in reduced fares (present worth $144 million).

three cost-effective strategies for reducing air pollution, along with the strategies of reducing transit waiting time ($9 million, 3 percent VMT reduction) and traffic flow improvements ($45 million, 10 percent VMT reduction). A recent energy conservation strategies analysis estimates a 4 to 6 percent reduction in regional energy use from fare reduction policies (6).

As for the use of fare reductions in conjunction with marketing, no analysis has been made to INTERPLAN's knowledge of the mutually reinforcing impact of these combined actions. The evidence of 1973-74 transit experience presented in Table 1-6 indicates, however, that their joint impacts on ridership can be far greater than the impact of fare reductions alone.

Implement Transit Integration (1.2.3)

As amply documented in INTERPLAN's 1973 study (136), the integration or coordination of European urban transportation systems is an important factor in their demonstrated success in holding transit patrons and attracting new ones. Institutional transit integration can take many forms, ranging from the highly centralized, single ownership of an enterprise like London Transport to the formalized but flexible contractual agreement between the members of the Hamburg Transit Federation. Some kind of institutional arrangement is required, however, before several transit operators can arrive at a successful regrouping of their physical and operational resources into a single transit system with a unified fare structure and route system. The importance of service integration has gained recognition in the U.S. over the past several years as local public bodies acquire individual private transit companies and undertake the responsibility for providing areawide service.

Short of repeating our evaluation of the degree of transit integration in U.S. cities and attempting to identify associated changes in ridership trends, an R&D effort which would yield more meaningful results if performed in the early 1980s, INTERPLAN can only re-emphasize the importance of this long-term action, and applaud efforts postdating its study in Washington, D.C. (Metro's purchase of local bus operators), New York City (creation of regional

Metropolitan Transportation Commission), San Francisco (steps toward Bay area transit federation), and in other cities which show movement in the right direction. The San Francisco story is of particular note because the transit federation being formed there appears to be patterned after the Hamburg federation described in detail in the INTERPLAN report (136, Vol. 2, Section 3, pp. 53-90). A February 1974 news item reports (146):

> "A transit federation" will be formed later this month by the general managers of the big five—the San Francisco Municipal Railway, Golden Gate Transit, Alameda-Contra Costa Transit, BART and Santa Clara Transit.
>
> "They will meet to agree on fare structures, transfers and coordinated schedules.
>
> "Six months ago, that was an impossible dream. . . .
>
> "The Bay Area abounds with regional groups, but most of them have been frustrated by timidity, red tape, jealous opposition from local groups, and above all, by lack of will.
>
> "The MTC, which has never been accused of boldness, has the potential power, however. Legislation in 1972 provided that the MTC must approve before state or federal grants can be bestowed for transportation purposes to Bay Area counties, cities or transportation districts.
>
> "That provision has become more important here. Until now, the MTC was distributing mainly sales tax receipts for public transportation—about $38 million annually.
>
> "But now the federal government has unveiled about $800 million a year for both buying and operating public transportation, and billions more are being proposed by President Nixon.
>
> "At the least, beginning this year, that means more than $25 million in additional funds available for the Bay Area—through MTC.
>
> "The MTC muscle, then, together with the gas crisis, means that for almost the first time officials in the Bay Area will be forced to make agreements as if they lived in one large city."

That the incentive for institutional integration here was provided by large sums of federal money and a national fuel shortage shows that federal capital and operating subsidies (strategy 1.1) can act as catalysts in the formation of American regional transit institutions capable of repeating European transit's success stories.

Besides the institutional, physical, and operational coordination of transit operators, improvements in management techniques were also cited in INTERPLAN's report as essential in bringing U.S. transit up to the level where patrons can be attracted in significant numbers. The creation of a new Office of Transit Management in the September 1973 reorganization of UMTA is an important sign that this question will now be granted the attention it deserves. Although improvement in management is not so easy to measure as fares or even service, a hopeful note is sounded in a recent Wall Street Journal article on transit (369), which quotes an UMTA official as saying that the newer transit authorities have better trained, more imaginative managers, but that heads of older companies are more experienced. INTERPLAN believes that if the resurgence of interest and patronage continues, more good managers and technical personnel will be attracted to transit, newcomers to the field will gradually gain the experience they need, and the new ideas and techniques they may introduce cannot help but rub off on older, established operations interested in sharing federal funds and recognition.

One area where all levels of management could profitably work together, perhaps through the industry's professional association, the American Transit Association (the name changes to American Public Transit Association in 1975), would be in the advocacy of industry-wide minimum service standards. Many transit systems, according to the Wall Street Journal article (369), have neither service contracts with public authorities, which spell out minimum standards of service that transit riders are supposed to enjoy, nor their own service standards, if they are not under public contract. As a result, the systems' performance cannot be consistently evaluated, and the quality of service depends not only on available funding but on managers' decisions. While UMTA is expressly forbidden by legislation from interfering with or regulating public transit operations, the development of guidelines for such standards could be a worthwhile task for UMTA R&D. Local transit management could use them as a yardstick against which to measure their performance and a set of goals to aim at and to sell to the public.

INTERPLAN firmly believes that the transit industry and transportation agencies have awakened to the importance of transit integration and management improvements; they should not be excluded from any action plan to attract transit ridership. Preferably, short-run actions to improve service, reduce fares and promote transit should be carried out within the broader framework of a unified and coordinated areawide transportation plan.

Improve Passenger Security (1.2.4)

EXPERIENCE. It has been suggested that at least part of the declining trend in transit ridership is attributable to increased transit crime, and that fear of crime continues to deter potential transit patrons. If this is true, then measures to restore passenger security could be crucial to the success of other actions to attract transit ridership and should not be omitted from an overall program. INTERPLAN found that while transit crime has risen in recent years, there is disagreement on the importance of this factor to riders and on the impact on ridership. The fact that the evidence is contradictory suggests that passenger security measures may be of vital importance in some cities but not in others.

A 1973 American Transit Association study of passenger security and vandalism (damage to property) estimates that about 35,000 incidents took place in 1971, or about one for every 170 million revenue passengers (11, p. III-10). No breakdown is available of personal vs property crimes, but about 8 percent of all incidents were classified as "violent crime". The total national cost of personal crime to transit systems from passenger claims is estimated by the same report at about $2 million a year. While there was a general overall rise in criminal incidents for most transit systems over the period 1969-71, there was much year-to-year irregularity and much variation between systems. The ATA report concludes that the extent of crime for a specific transit system depends very much on the local situation and cannot be predicted with any precision from such facts as the size of the system, city population, or overall city crime rate.

In general, transit crime is more serious on rail systems than on bus and during off-peak than peak hours. A paper presented at the 1974 Highway Research Board meeting (262) found that in Chicago, 75 percent of transit crime, most of it robberies, occurred on the rapid transit system. By time of day, two-thirds of rapid transit robberies took place between 6:00 p.m. and midnight, while assault and battery occurred more often when the system was congested, peaking during the 5-6 p.m. rush hour. The high risk periods for both bus and rail systems were weekends and late night and early morning off-peak hours. Geographically, the rate of criminal incidents was closely linked to the rate of unemployment and to the level of crime in the surrounding area.

The ATA report and the HRB paper do not agree on whether the risk of exposure to crime is greater on transit systems than in cities in general. The latter estimates a robbery rate in Chicago of 332 per 100,000 members of the "transit community", or about one-third the rate for robberies in the community in general (262, p. 17). The ATA report, which takes into account the fact that transit riders are exposed to transit crime for shorter periods than they are exposed to general crime, concludes that the risk of being involved in a criminal incident could be at least twice as great when riding on urban mass transit vehicles as in non-transit circumstances (11, pp. III-16 & 17). Their "transit violent crime exposure index" is greater than the "F.B.I. violent crime exposure index" for 9 of the 14 transit systems investigated.

IMPACT ON RIDERSHIP.* Equally great variation is shown in the results of attitude surveys to determine whether or not people consider transit systems "safe" and what impact transit crime has on their decision to use or not to use transit. An ATA survey of passengers on one bus route in Milwaukee led to the conclusion that transit crime did not have a major influence on passenger ridership; a similar survey administered to riders on one bus route in Washington, D.C., indicated that it did. Some light is shed on the issue by another ATA survey of both users and non-users of transit, which indicated that personal safety is of greatest concern to those who might ride rail systems or travel at off-peak hours: people are much less fearful of riding on buses than on rapid transit, non-working women often chose rush hours for rapid transit trips, and few people ride at night or on weekends.

OVERALL EVALUATION.** There is no consensus on how much fear of crime actually influences ridership decisions, or how much ridership could be increased if security on transit systems were improved. There does seem to be a general agreement that fear of crime is a significant deterrent to night transit ridership, and perhaps to off-peak ridership in general. As the ATA report points out, the effect of the influence of fear of transit crime depends on other factors which vary from system to system, such as the volume of crime in specific areas or on specific routes and the available transportation alternatives. The HRB paper notes that passenger security will become an increasingly important issue if there is a great expansion of rail rapid transit systems into suburban areas, where transit success will depend on attracting commuters from their cars.

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*The broader impacts of an auto-transit switch due both to increases in capacity (1.1) and to all measures to attract transit ridership (1.2.1 through 1.2.4) are discussed on pp. 1-8, 1-12 - 1-13, and summarized in Table 1-2 (pp. 1-9 - 1-11).

**An overall evaluation of the combined effectiveness of the strategies to increase transit capacity (1.1) and attract transit ridership (1.2), to which this action would contribute, is given on p. 1-13.

Where a need for passenger security measures is identified, the following measures are cited as potentially the most effective; they are described in detail in Reference 11:

CRIMINAL DETERRENT AND DETECTION MEASURES

All Systems

- Police or Security Force Patrol and Surveillance
- Non-professional Surveillance
- Police Dogs

Rapid Transit Stations

- Public or Direct-Connection Phones
- Closed Circuit Television Surveillance
- Station Design Factors

Rapid Transit Vehicles

- Helicopter Surveillance

Bus Systems

- Alarms and Signals
- Automatic Vehicle Monitoring Systems
- Two-way Radios
- Bus Shelters

EDUCATIONAL DETERRENT PROGRAMS

While each transit system must determine the security measure or combination of measures which is the most effective at the least cost, control of crime depends mainly on rapid police response to incidents, not necessarily on large-scale use of patrols or TV cameras. Transit riders tend to feel most secure when they feel that assistance can be readily obtained in an emergency (262).

INCREASE PARA-TRANSIT CAPACITY AND USE (1.3)

Introduction

While the potential role which transit could play in urban transportation is not difficult to project on the basis of past U.S. experience and current European experience, the future role of para-transit as an auto alternative must be extrapolated from limited recent experience. On the basis of INTERPLAN's appraisal of this experience in this subsection, a 10 percent share of total 1990 urban PMT is assigned to the demand-responsive 12-passenger minibus para-transit mode in the Volume 2 analysis of the impacts in 1990 of the "maximum conceivable" diversion of auto to transit and para-transit modes (see 144a, Section 2, p. 11). With this substantial a market share, assumed to be diverted entirely from the auto mode, para-transit is carrying roughly the same number of passenger miles as the bus mode, and from half to two-thirds as many as the rail modes; in terms of VMT, para-transit vehicles account for 4 percent of the total, or as many as bus, rail and taxi modes combined (auto carries 92 percent of 1990 VMT).

Thus it is INTERPLAN's position that the potential future role of para-transit in diverting auto trips could be a major one. Evidence to support this position and an appraisal of the overall impact of an auto-to-para-transit switch on mobility, air quality, and energy use should logically be examined separately from the impacts on ridership of actions which encourage this switch. For this reason, a review of para-transit experience, of its impact on the goals, and an overall evaluation of the strategy to increase para-transit capacity and use (1.3) is presented next. Brief discussions of the effectiveness of providing implementation guidance (1.3.1), capital and operating subsidies (1.3.2), and eliminating market restrictions (1.3.3) as actions which promote the overall strategy are reserved for the end of the subsection (see p. 1-55). A much fuller treatment of recommended actions is contained in INTERPLAN's forthcoming report, Potential for Flexicab Services in Urban Transportation (7348R) (Ref. 145).

EXPERIENCE. The term "para-transit", like "transit", includes a number of different modes and vehicle types. In general, para-transit is dis-

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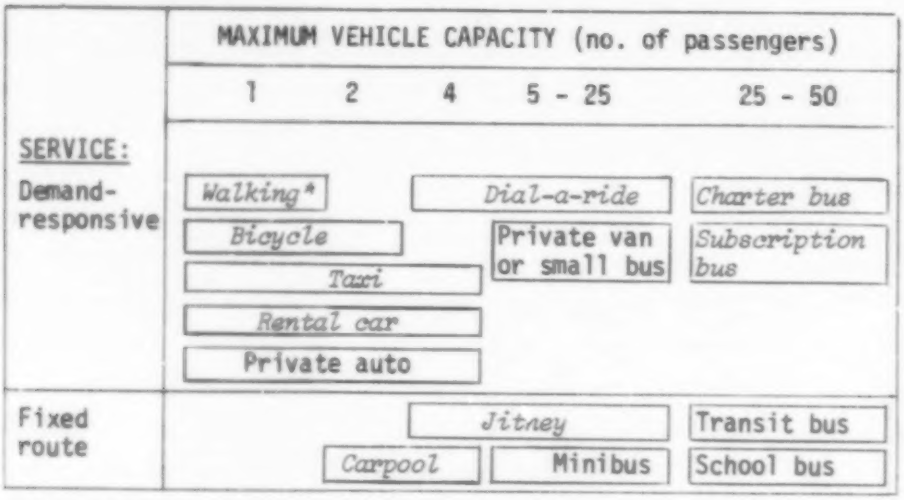
tinguished from transit either by the smaller vehicles used, the provision of demand-responsive services, or both, as shown in Figure 1-1.



*Para-transit modes in italics.

Figure 1-1. Definition of para-transit modes by vehicle capacity and service characteristics.

In this discussion, we focus on the dial-a-ride mode, which may be offered by a taxi company or a transit company and may use vehicles carrying anything from 4 to 25 passengers. This is the para-transit mode which best fills the present gap between the high-cost, high-quality, low-occupancy modes (taxi, rental car, private auto) and the low-cost, low-quality, high-occupancy modes (bus, rail). Carpools and buspools (3.1) and pedestrian and bike modes (1.4), also broadly considered as auxiliary ("para") to transit, are dealt with elsewhere in this report. As for jitneys, they are most useful in what is essentially a transit service, running during off-peak hours and providing peak-period capacity to supplement the regular transit vehicles.

INTERPLAN's summary of the operating experience of seven major dial-a-ride systems is presented in Table 1-8, which consolidates information from the six most recent major surveys of para-transit experience (19, 113, 164, 247, 287, and 332). All but one were published in 1974 (287, November 1973); three were prepared for UMTA and one for its Canadian counterpart. The seven systems in the table are among the oldest and most successful of the 70-odd systems in operation as of the summer of 1974. One impressive characteristic of

Table 1-8. Characteristics of 7 major dial-a-ride systems.

	Ann Arbor, Michigan	Batavia, New York	Bay Ridges, Ontario (Canada)	Davenport, Iowa	Haddonfield, New Jersey	Hicksville, New York	Regina, Saskatchewan (Canada)
GENERAL							
Date Service Initiated	Sept. 1971	Oct. 1971	July 1970	ca. 1930	Feb. 1972	1961	Sept. 1971
Service Operated By	Public transportation authority	Public bus company	Public transportation authority	Private taxi company	Public transportation authority	Private taxi company	Public transit company
Service Area Population	10,000	18,000	14,500	98,500	40,000	48,100	32,000—peak 58,000—off-peak
Service Area (sq. mi.)	2.3	4.3	4.0	19.7	10.9	6.8	5.0—peak 8.5—off-peak
Population Density (persons/sq. mi.)	4,300	4,200	3,600	5,000	3,700	7,100	6,400—peak 6,800—off-peak
SERVICE							
Type of Service:							
Peak	M-F; F-M	M-M	M-O; O-M (Sub.)	M-M	M-M; M-O (Sub.)	M-M	M-O; O-M (Sub.)
Off-peak	M-F; F-M	M-M	M-M	M-M	M-M	M-M	M-F
Percent of riders using various services	N/A	Sub. - 58% M-M - 40%	M-O - 80% M-M - 20%	N/A	Transit feeder-34%; shopping center - 21%	N/A	Arterial bus feeder - 55%; M-F - 35%; M-M - 10%
Hours of Service	6:30am - 6:30pm (Mon.-Fri.); 8:00am - 6:00pm (Sat.)	6:00am - 6:00pm (Mon.-Fri.)	5:00am - 1:00am (Mon.-Sat.)	24 hrs. a day, 7 days a week	24 hrs. a day, 7 days a week	24 hrs. a day, 7 days a week	5:25am -12:00am (Mon.-Fri.) 6:40am -12:00am (Sat.) 1:00pm - 8:40pm (Sun.)
Special Services Offered	N/A	Subscription; package delivery; charter	Subscription	Package, ice, money & telegram delivery	Subscription	Telegram delivery	Subscription

Table 1-8. (continued)

	Ann Arbor, Michigan	Batavia, New York	Bay Ridges, Ontario (Canada)	Davenport, Iowa	Haddonfield, New Jersey	Hicksville, New York	Regina, Saskatchewan (Canada)
Vehicles in Service:							
Peak (capacity)	3 (10 pass.)	4 (19 pass.) 1 (10 pass.)	3 (11 pass.) 1 (23 pass.)	20 (5 pass.)	14 (10 & 17 pass.)	26 (5 pass.)	6 (15 pass.) 5 (23 pass.) 1 (45 pass.)
Off-peak (capacity)	3 (10 pass.)	3	2	16 (5 pass.)	10	26 (5 pass.)	8
Average Wait Time (min.)	15 - 20	10 - 20	45	15 - 25	25 - 30	8 - 10	30
MARKET							
Ridership:							
Daily average	190	400	600	1,269	1,331	900	3,400
Per vehicle-hour	8	10	11	5	6 - 7	3	19
Demands/sq. mi./hour	6.9	7.8	7.5	2.7	5.1	5.5	28.2
Market Share	2%	1 - 2%	3 - 4%	2 - 3%	5 - 6%	N/A	6 - 7%
Alternative Public Transportation	Bus and taxi	Taxi	Taxi (system feeds commuter rail)	Bus	Taxi (system feeds commuter rail)	Bus	Taxi (system feeds arterial bus routes)
LABOR AND COSTS							
Drivers	Union	Non-union	Union	Non-union	Union	Non-union	Union
Hourly Wage	$5.50	$3.30	$3.30	$2.65	$6.50 - 7.00	$2.29	$5.50 - 6.00
Average Revenue/Trip	$ .45	$ .45 - .50	$ .28	$1.03	$ .53	$1.79	$ .32
Revenue/Vehicle-hour	$2.80	$4.00 - 5.50	$3.10	$5.15	$3.50	$5.30	$5.50 - 6.00
Operating Cost/ Vehicle-hour	$6.00	$5.00	$5.00	$4.67	$8.00 - 10.00	$3.53	$7.00
Total Cost/Vehicle-hour	$10.80	$7.00	$6.60	$4.97	$15.00 - 16.00	$3.70	$11.00

Notes: M-F = Many to Few; M-M = Many to Many; M-O = Many to One; Sub. = Subscription Service; N/A = Not Available.

Sources: 19, 113, 164, 247, 287, 332.

the dial-a-ride mode is the rate at which is it growing; less than half-a-dozen were initiated in the 1960s, compared to over 60 in the 1970s, including over two dozen in 1974 alone. Only five of these are known to have failed (332, p. 12). Most of the earlier dial-a-ride services were established in smaller urban areas (less than 100,000 population), but since 1973, roughly a third of the cities setting up new services have been major metro areas (e.g., Los Angeles, New Orleans, Cleveland, St. Petersburg, Toronto). Most services in operation as of May 1974 had fleets of 7 or fewer vehicles and charged fares of 50¢ or less (332, p. 12).

The following conclusions have emerged from INTERPLAN's review of operating experience to date:

1. Para-transit has five major advantages over bus transit:
   a. It attracts higher levels of ridership, even at much higher fare levels. A substantial proportion of new riders are former auto riders or drivers (25 to 50 percent), while as much as 50 percent of the new ridership is new induced demand.
   b. It attracts a greater variety of riders, both special groups (the old, the young, the poor, and minority groups) and high-income commuters.
   c. It is more flexible in responding to seasonal and daily fluctuations in travel demand and in serving low-density areas.
   d. It has more potential short-term impact on the three urban goals because, due to the greater availability of vehicles, it can be expanded faster than conventional transit.
   e. Para-transit systems, while usually not breaking even, generally require lower subsidies than conventional bus systems, while providing higher quality service.
2. At the present time, taxi companies can offer dial-a-ride services more economically than transit companies can, because taxi vehicles are smaller and less expensive, and because taxi companies have the benefit of experience in dispatching and routing and face fewer labor and wage constraints.

Other lessons learned from current experience regarding the applicability of para-transit to specific demand conditions, the economic characteristics of para-transit operations, and the constraints imposed by local government regulation of operations are discussed as appropriate within the context of the individual actions for stimulating para-transit capacity and use (see pp. 1-55 - 1-61).

IMPACTS ON GOALS. Para-transit's potential impact on mobility, air quality, and energy use depends on three factors:

1. The percent of the total urban transportation market which para-transit captures.
2. The percent of para-transit trips diverted from auto and non-auto modes (transit, taxi, walking), and the percent of trips which are new induced demand.
3. The pollution and energy consumption characteristics of para-transit vehicles.

For the purposes of the Volume 2 analysis, para-transit's 1990 market share was postulated at 10 percent of total PMT; all para-transit travel was assumed to be diverted from auto travel; and para-transit emission and fuel use characteristics were taken to be those of a 12-passenger vehicle (see 144a, Table 3, p. 16). While other assumptions might just as plausibly be postulated for this type of long-range analysis, INTERPLAN feels that the assumptions used best reflect the trends emerging from current para-transit developments.

Market Share. To date, dial-a-ride operations have been able to attract only a small fraction of total area trips in their service areas: 5-6 percent in Haddonfield, NJ; 1-2 percent in Batavia, NY; 3 percent in Bay Ridges, Ontario; 6-7 percent in Regina, Saskatchewan; 2 percent in Ann Arbor, MI; and 2-3 percent in Davenport, IO (see Table 1-8). However, two strong trends observed in these systems point to an eventual 10-15 percent para-transit share:

1. Ridership increases are still continuing after two years of service.
2. Expansion of service areas results in ridership increases proportionally greater than the increase in numbers of persons served.

With regard to the first trend, historical data on approximate mean riders per working day for four systems indicates sustained ridership increases of 10-25 percent per month, even without expansion of primary service area (164, p. 191). With regard to the second trend, it is typical for dial-a-ride services to be offered initially on an experimental basis in a limited service area. As long as the vehicles can serve only those trips which both start and end within the service area, the para-transit service will be prevented from competing for a large number of trips between points within the area and points outside it. Thus expanding the service area not only brings in new potential riders, it also increases the proportion of trips originating or terminating in the initial service area which can be made by dial-a-ride.

Thus in Haddonfield, after the first service area expansion, which increased the size of the area by 26.5 percent (6.4 to 8.1 square miles) and the population served by 13 percent (24,381 to 27,460 persons), there was a 50 percent increase in ridership. About half of this increase could be attributed to other factors, leaving a 25 percent increase in ridership as a result of a 13 percent increase in potential riders (185). Even so, the current size of the Haddonfield area prevents dial-a-ride from competing for 66 to 80 percent of the 470,000 trips per week made by area residents, since these trips are between points in and points outside the service area. It is estimated that in Haddonfield the demand would more than double and the market share would increase if an adjacent area of equal size and population characteristics were to be incorporated into the service area (374, p. 348).

Similar increases in demand and market share can be anticipated for other established para-transit services, since many limited first-generation demand-responsive systems are being expanded: the Regina system is doubling in size, the Ann Arbor system will be expanded to serve the entire metropolitan area, the Batavia system is being expanded throughout the Rochester metropolitan area, and the Bay Ridges system is being expanded within metropolitan Toronto (247, p. 334).

INTERPLAN's estimate of 10 percent as the eventual market penetration of para-transit is supported by an early (1971) economic analysis published by the Highway Research Board which predicted that dial-a-ride could attract 15 percent of daily trips. The analysis was based on a survey of about 1,100 households in an incorporated city of 200,000, located within a major metropolitan area and having limited transit service. The highest estimated ridership on a dial-a-ride system was found to be approximately 15 percent of all internal trips for a system with a 50¢ fare and the shortest specified service times. All of the market subgroups indicated significant use of the system at this fare, in general more for shopping and work trips than social-recreation or personal business trips. The analysis concluded that at this fare level, a dial-a-ride system "would indeed compete with the existing automobile mode of travel." (103, p. 126)

Diverted and Induced Travel. In INTERPLAN's Volume 2 analysis, it is assumed that in 1990 all new para-transit riders are diverted from auto and that there is no induced travel. These assumptions are made to simplify the analysis and do not reflect the complexities of travel pattern changes following initiation of a new service. While it is felt that the limited data available is inadequate for quantitative conclusions at this early stage in para-transit history, the indications are that from 25 to 50 percent of new para-transit riders used to make the trip as auto drivers or riders prior to the introduction of dial-a-ride service. According to Ref. 164 (p. 200), in Bay Ridges, Ontario, about half of the dial-a-ride patrons are former auto riders; in Regina, about 24 percent; in Haddonfield, 25 percent. Depending on the assumptions used about the proportion of former auto riders vs former auto drivers, and the alternative use of the car, this diversion implies one of the following:

1. No change in auto VMT. This applies if the drivers of former auto passengers continue to make the auto trip alone, and if the cars freed by former auto drivers are used for new auto trips.
2. Reduction in the number of auto VMT corresponding to the increase in para-transit PMT. This applies if the drivers of former auto passengers discontinue making the trip because their only reason for making it was to chauffeur the passenger, and if the cars freed by former auto drivers are not used for any new trips.
3. Reduction in the number of auto VMT corresponding to the increase in para-transit PMT plus an increase in transit PMT. This applies if the conditions for (2) hold, and if the convenience of para-transit as a feeder mode to transit attracts former drivers to the para-transit/transit alternative.
4. Reduction in auto VMT falling somewhere between (3) and (1).

If induced travel is taken into account, it is conceivable that net VMT could increase if case (1) above holds, and if enough new trips are generated by the introduction of new para-transit service. Of the three systems on which data are available, two reported about 50 percent (Ann Arbor) and 25 percent (Haddonfield) of para-transit riders would not have made the trip without dial-a-ride (164, p. 200; 287, p. 19), but the third (Regina) reported only 3 percent of trips were new (279, p. 28). Results of a 1971 survey support the lower figure: "Latent demand, as measured by the increase in the number of trips being made as the result of the availability of the new mode, was small even for the 50¢ [fare] system with the shortest specified service times; an increase in total internal trips of 0.5 percent of all trips was recorded for this system." (103, p. 126)

While the lower figures for induced trips may be interpreted to mean, as in the quoted reference, that dial-a-ride "should therefore be considered in terms of providing a competitive or complementary mode to the automobile (depending on the fare level) rather than in terms of solving serious transportation problems of immobility" (103, p. 126), it also seems quite possible that the need for greater mobility by car-less groups is simply lower in Regina and in the middle-income survey city than it is in Ann Arbor and Haddonfield, where a substantial amount of new trips were induced. Where there is substantial latent demand for mobility, there will be an implied tradeoff between improving mobility by adding para-transit and keeping congestion down by avoiding anything which would increase VMT, including para-transit service.

However, there is a countervailing complementary relation in cases where the dial-a-ride replaces fixed bus routes, since some unnecessary mileage is avoided because vehicles may skip route portions having no demands. In Regina, where the "Telebus" dial-a-ride system replaced two of 6 fixed routes, revenue vehicle miles declined nearly 5 percent (563,000 to 536,000). Since at the same time passengers carried increased by 15 percent (2.0 million to 2.3 million), the substitution of the two dial-a-ride routes also increased passengers per revenue mile, a measure of efficiency, from 3.5 to 4.2 (20 percent). In Columbus, Ohio, the change was even more dramatic: a demand-responsive route carried roughly the same number of passengers as the fixed route line it replaced but incurred only one-half the route miles (247).

In conclusion, the impact on VMT of introducing a dial-a-ride system is indeterminate unless some assumptions are made regarding travel behavior and the nature of the service offered (door-to-door or transit feeder). It is INTERPLAN's feeling that the most plausible assumptions are that:

1. Auto trips will indeed be substituted by dial-a-ride, but not as great a reduction in VMT will result as implied by the number of former auto passengers and drivers because some new auto VMT will be generated by other drivers of the freed autos.
2. New VMT created by dial-a-ride induced travel will not be sufficient to offset VMT reductions due to the switch from auto.

3. Even if induced dial-a-ride travel were to add to net VMT, this undesirable effect should be weighed against the gain in mobility by persons not previously able to travel.

4. Dial-a-ride is likely in the future to generate substantial amounts of *transit* travel, since operators are expected to follow the example of the Regina and Bay Ridges systems, where para-transit acts as a feeder to transit as well as providing door-to-door service. The portion of this transit travel diverted from auto will reduce auto (and total) VMT, while the portion which is induced travel will be a net contribution to urban mobility.

On balance, then, it is believed that dial-a-ride systems will reduce VMT and increase mobility, but by how much will depend on the travel characteristics of the population served and on the nature of the services offered.

Vehicle Emission and Energy Use Characteristics. The vehicles used for dial-a-ride and other para-transit services range from taxis to 23-passenger minibuses (see Table 1-8). In INTERPLAN's survey of operators for its forthcoming flexicab study, it was found that capacity over 12 passengers per vehicle is generally regarded as superfluous and uneconomical by most operators; for this reason the 12-passenger minibus was adopted as the representative para-transit vehicle in the Volume 2 analysis of 1990 diversion of auto travel to transit and para-transit. The emission and energy use characteristics of this vehicle type, as well as those of taxis, are given in Volume 2, Table 3 (144a, p. 16).

While emissions per para-transit vehicle are 20 percent higher than for autos, and energy use 50 percent higher, per passenger emissions are two-thirds lower and energy use one-third less at the assumed average capacity. The overall effect of para-transit service will obviously depend on the extent to which high-occupancy para-transit VMT substitute for low-occupancy auto VMT, and the extent to which new para-transit VMT are induced. If INTERPLAN's above-stated assumptions on these factors are maintained (see p. 1-51), then para-transit's effective (per passenger) emission and energy use characteristics will be an improvement over auto's. Their relative position will doubtless benefit from the results of UMTA's low-pollution para-transit vehicle R&D project (RFP DOT-UT-40020).

OVERALL EVALUATION. The results of the Volume 2 analysis show that the postulated diversion of 10 percent of 1990 PMT to the para-transit mode contributes roughly a fifth of the energy savings implied by the total auto shift, and about a quarter of the total CO and HC emission reductions (see 144a, Table 6, p. 26). The total energy savings and HC and CO reduction is about 30 percent over the no-diversion case, while NO_x emissions are 18 to 30 percent higher. The contribution of the diverted travel carried by para-transit to the total savings is about 7 percent for energy and 8 percent for emission reductions (see 144a, Table 5, p. 24). Para-transit's contribution is greater than that of the bus mode, despite the larger share of PMT assigned to bus (144a, Table 2, p. 12), but less than that of rail systems, under the assumptions of Volume 2.

INTERPLAN located one other attempt to evaluate the impacts of para-transit in a recent Urban Institute report (164). The Urban Institute report conclusions appear to be consistent with INTERPLAN's despite the difference in underlying assumptions, approach, and definitions. While INTERPLAN's Volume 2 examines the impact in 1990 of diverting 10 percent of auto travel to para-transit, the Urban Institute report's conclusions are based solely on present operating experience. It concludes that dial-a-ride's effects on congestion, energy use and pollution are three times as great as those of private autos, while those of subscription bus and carpools are half as great as auto's (164, p. 381). An earlier version of the same report evaluates dial-a-ride's potential for reducing congestion, pollution and energy consumption as "medium" in low-density and business district applications and "low" in feeder service applications, as shown in the table below from that report. Para-transit modes receiving the "high" ranking for feeder service applications were carpools and subscription bus or taxi. All three modes (dial-a-ride, carpool, and subscription bus) are evaluated as having high importance to mobility.

The apparent divergence between these conclusions and those of INTERPLAN can be reconciled by recognizing that INTERPLAN's 1990 para-transit mode is defined only with respect to vehicle size and not with respect to function; there is no reason why INTERPLAN's 12-passenger minibus cannot provide

Table 1-9. Urban Institute ranking of potential impacts of para-transit applications.

Para-Transit Application	Potential Impacts (H=High, M=Medium, L=Low) Importance to Mobility	Potential Impacts (H=High, M=Medium, L=Low) Potential for Reducing Congestion, Pollution, Energy Consumption
High Density Home-to-Work Travel		
Jitney	M	M
Carpool	H	H
Subscription Bus	H	H
Low Density Travel Demand — Substituting for Conventional Transit		
Taxi	H	M
Dial-a-Ride	H	M
Feeder Services		
Short-term Rental Car	L	L
Taxi, Dial-a-Ride	M	L
Jitney	L	L
Carpool	H	H
Subscription Bus or Taxi	H	H
Business and Commercial Districts		
Short-term Rental Car	L	L
Taxi	H	L
Dial-a-Ride	H	M
Jitney	H	M
Access to Inter-City Terminals		
Daily Rental Car	H	L
Taxi	H	L

Source: Reference 163, Vol. III, p. 9.

subscription services as well as dial-a-ride or any other para-transit service which proves to be a viable auto-substitute. However, the Urban Institute report's conclusion on the role of para-transit vs transit and auto offers an important qualification to INTERPLAN's more optimistic assumptions in Volume 2 (164, pp. 48-49):

> "The urgent need for higher-occupancy transportation services to curb pollution and fuel consumption cannot be met fully by conventional transit; urban bus systems simply do not have the system capacity to substantially expand peak-hour services in the near future. Para-transit services such as jitney, car pool, van pool, and subscription bus, offer a promising means of reducing pollution and fuel consumption per passenger trip while maintaining a relatively high level of mobility. It should be noted, of course, that higher occupancy travel in itself has only limited potential for reducing overall pollution and fuel consumption. While passenger cars account for almost 80% of all vehicle miles traveled on U. S. streets and highways, 58% of passenger car miles are for the purposes of family business, education, social activities, and recreation, and are already conducted with an average of more than two occupants per vehicle. It is doubtful that transit or para-transit services (such as dial-a-ride) can effect savings in pollution or fuel consumption per passenger trip for low density trips in this latter category; if such trips are to be made, the private automobile may well be the most efficient mode for the purpose."

The remainder of this subsection is devoted to brief descriptions of the three actions which INTERPLAN feels would do most to promote the strategy just reviewed: increase para-transit capacity and use (1.3).

Provide Implementation Guidance (1.3.1)

Two of the six basic sources on para-transit cited in Table 1-8 also give valuable guidelines for the types of service areas and services where para-transit would best be applied. The Urban Institute report recommends three major types of services:

1. Low density travel demand (suburban areas, small urban areas, off-peak hours, limited mobility groups).
2. Feeder service to line-haul transit.
3. Shuttle service within business and commercial districts.

INTERPLAN's evaluation of para-transit's suitability for providing these types of services is given in Volume 2 (144a, pp. 56-60). All three types of services are serving markets with demand levels too low for conventional transit. Conventional bus transit requires at least 80 demands per square mile per hour along a corridor, while demand-responsive transportation can be viably operated with as few as 20 demands per square mile per hour (113).

With demand rates of less than 10, productivity falls off very steeply. Assuming conservative ridership attraction and modal split, demand-responsive systems can serve areas with population densities of up to 8,000 persons per square mile. This is the range of areas experiencing the most rapid growth today and the one which cannot adequately be served by conventional bus or rail. Even in very low density areas (less than 4,000 persons per square mile) where no transit service can be justified on economic grounds alone, demand-responsive systems offer the best possible transit alternative to meeting mobility needs.

Table 1-10 gives levels of service for demand-responsive operations recommended in a recent CalTrans review of para-transit state-of-the-art, and Table 1-11 summarizes the guidelines in the Canadian dial-a-bus manual (287) in the form of a "readiness for dial-a-bus" scoring sheet to determine the suitability of a region for this service.

Table 1-10. Recommended levels of service for demand responsive operations.

	Levels of Service		
	Minimum	Desirable	Maximum
Service Area (square miles)	1.0	5.0 - 8.0	20.0
Population Density (persons/square mile)	1,000	>3,000	*
Demand Density (demands/sq. mile/hour)	10	20	*
Average Productivity (passengers/sq. mile/hour)	10	20	**
Average Wait Time (minutes)	*	10-15	30
Average Ride Time (minutes)	*	<2.0 times auto trip time	<4.0 times auto trip time
Vehicle Size (number of passengers)	5	5-12	20-25
Average Fare	***	***	***

*No limit.

**No systems have seemingly reached capacity.

***This is a policy decision. Demand responsive transportation can be economically viable depending on the particular policy in operation for a given area.

Source: Reference 13, p. 33.

Table 1-11. Suggested range of variables to determine readiness for dial-a-bus applications.

VARIABLE	POINTS*	DESCRIPTION	REMARKS
POPULATION	1	Below 4,000 or above 50,000	Based on: -Demand-Activated Transportation Systems, HRB Special Report No. 124,1971 -Roos, D.et al., Summary Report - The Dial-a-Ride Transportation Systems, USL TR-70-10, M.I.T., March 1970
	2	Between 20,000 and 50,000	
	3	Between 4,000 and 20,000	
DENSITY (persons per square mile)	1	Below 2,000 or above 10,000	-Roos, D., Operational Experience with Demand-Responsive Transportation Systems Research Report R72-2,paper presented at HRB meeting, Washington D.C., Jan. 1972 -Report on Dial-a-Ride Technology Twin Cities Area Metropolitan Transit Commission, TCA MTV-TD-72-01, July 1972 An area with less than 20,000 is initially desirable because low capital investment is needed for implementation a small system is easy to monitor and analyse manual dispatching is adequate
	2	Between 6,000 and 10,000	
	3	Between 2,000 and 6,000	
SOCIO-ECONOMIC CHARACTERISTICS Captive user factor	1	Low proportion of persons aged 5 - 18 or over 65	Based on the above and the following reports: -Guenther,K.W.,Summary Report,Phase I Results; Ann Arbor Dial-a-Ride Program, FTRPO, 1972 -Guenther, K.W., The Mansfield Dial-a-Ride Experiment, FTRPO, October 1970 1970 -Dial-a-Bus, the Bay Ridges Experiment, Ontario Department of Transportation and Communication, August 1971 Note that the income groupings must depend on local conditions.
	2	Higher proportion of persons aged 5 - 18 or over 65	
	3	Highest proportion of persons aged between 5 - 18 or over 65	
Income per household per year	1	Low to medium income relative areas (under 6,000)	
	2	High income relative to other areas (over 10,000)	
	3	Medium to high income relative to other areas (from 6,000 to 10,000)	
PUBLIC TRANSPORTATION QUALITY Availability (ratio per square mile)	1	Highest transit route length	This measures the coverage of transit routes. The higher the ratio, the better the coverage. A low ratio means long walking time to transit routes.
	2	High transit route length	
	3	Low transit route length	
Quality	1	Highest frequency of service at peak hours	This measures the waiting time required for transit service. A low frequency suggests long waiting time.
	2	High frequency of service at peak hours	
	3	Low frequency of service at peak hours or no transit service at all	

Table 1-11. (continued)

VARIABLE	POINTS	DESCRIPTION	REMARKS
Distance from nodal point(e.g. rapid transit station,commuter trains or subways) and transfer point to line-haul fixed bus routes	1 2 3	Very close to a nodal point (within walking distance) or farthest away from a nodal point (over 30 minutes round trip) Remote from nodal point but within 20 - 30 minutes round trip Adjacent to nodal point and within 10 - 20 minutes round trip	This measures the efficiency of D.A.B. as a feeder service to rapid transit lines or line haul fixed route bus systems. When the area is very close to the nodal point,people may choose to walk, or when the area is very far from the nodal point, D.A.B. trip time may become too long to be acceptable.
Transit improvement potential	1 2 3	Low potential Medium potential High potential	This measures whether D.A.B. will be an effective tool to increase conventional transit patronage.
INTERNAL TRIP GENERATORS No. of activity centres in service area	1 2 3	Few or no activity centres High number of activity centres Highest number of activity centres	This measures whether there is sufficient transit demand for internal trips.
Employment density (ratio to population)	1 2 3	Low internal employment opportunities High internal employment opportunities Highest internal employment opportunities	This measures the potential demand for internal work trips and inflow of commuter trips from other areas.
Student density (ratio to population)	1 2 3	Low number of local schools High number of local schools Highest number of local schools	This measures the potential demand for internal school trips and inflow of school trips from other areas.
TRANSIT DEMAND PER SQUARE MILE PER HOUR	1 2 3	Less than 10 or over 80 demands 10 - 20 or 60 - 80 demands 20 - 60 demands	Dial-a-Bus is best for demands of 20-60 per square mile per hour. Under 10, the taxi may be a better alternative whereas over 80, fixed route bus is more efficient.

*Key:

Point 1 - Inappropriate or not very favorable for dial-a-bus service;
Point 2 - Fair to good prospects for dial-a-bus service;
Point 3 - Excellent prospects for dial-a-bus service.

SOURCE: Reference 287, pp. 40-41.

Provide Capital and Operating Subsidies (1.3.2)

Although their subsidy requirements are not as great as those of bus and rail systems, para-transit systems, at least at present, do require some subsidy. The present structure of federal assistance to public transportation to some extent discourages the channeling of funds to para-transit, first because the emphasis is on capital subsidies,* and secondly, because the labor protection provisions of the Urban Mass Transportation Act may discourage private para-transit operators from applying for federal aid (see 1.3.3 below, p. 1-60). If some form of operating subsidy is made available, and if private taxi companies are willing to absorb the eventual rise in labor costs which is likely to result once they agree to the labor provisions, the growth of para-transit systems will receive an important boost.

Even though they are not breaking even, most dial-a-ride systems require less subsidy than conventional bus systems while providing much higher quality service. Notably, in Regina the overall transit deficit decreased $45,000 the year after dial-a-ride was introduced due to a combination of increased passenger revenues and decreased costs resulting from modification of the fixed-route bus system (247, p. 333). An even greater decrease of $67,000 is reported for the Regina system by a later document (332).

Dial-a-ride usually incurs less of an operating deficit than fixed-route service despite its higher costs per passenger mile** because it attracts more riders at a higher fare and because it allows discontinuation of unprofitable fixed routes. In Batavia, for example, ridership and revenues had been declining on the fixed-route service which was in operation before the dial-a-ride system was started. Annual ridership was roughly 80,000 and the annual operating deficit had reached about $7,000 even though the vehicles were fully depreciated. Introduction of dial-a-ride service reversed the declining trend, attracted roughly 30 percent more riders during the first year of operation in spite of higher fares, and raised farebox revenues to the point where the system now meets all of its operating costs and a part of its fixed costs (164, p. 218).

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*This was written before passage of the 1974 NMT Act. See Note, p. ii.

**INTERPLAN's cost estimate for para-transit and other urban transportation modes are given in Table 7 of Volume 2 (144a, p. 27).

However, most dial-a-ride systems to date are still not breaking even. The exceptions are the taxi-based systems in Davenport, Iowa and Hicksville, New York, and the bus-based system in Batavia, New York. The taxi-based systems are more financially solvent for four reasons: taxi systems use smaller, less expensive vehicles; taxi operators have had more experience with dispatching and flexible routing; taxi drivers generally have much lower wage scales (in 9 major cities the hourly wage rates for bus drivers were consistently 50 percent higher than for taxi drivers, tipping excluded); and taxi dial-a-ride systems charge much higher fares than other dial-a-ride systems (164, pp. 202-203). The Batavia system's better financial position is due to the fact that it derives substantial revenue from services such as subscription bus, package delivery, and charter service which it provides in addition to the basic many-to-many service (164, p. 218).

While most dial-a-ride systems are not at present breaking even, it is felt that there is considerable scope for reduction in costs, which have sometimes been exceptionally high due to inexperienced management and costly monitoring functions (164, p. 232). Furthermore, ridership on most systems has been growing steadily and further increases in revenues can be expected, both from further ridership increases and also from fare increases. Riders would probably tolerate fares quite a bit higher than those now charged, because demand is known to grow more elastic with respect to fares as the quality of service becomes more competitive with that of auto (157, p. 39).

Eliminate Regulatory and Labor Restrictions (1.3.3)*

Regulations restricting the types of services which taxi and transit operators may offer and the geographic areas in which they may operate, and legislation restricting labor practices of para-transit operators receiving federal grants, constitute constraints to the type of flexible operation which para-transit is best suited to provide. These restrictions tend to favor the use of a public transit operator to provide new services, even though a private para-transit operation might be able to provide the same service at lower cost. Certainly there is agreement that the taxi industry should be deregulated to permit taxis to operate shared-ride and jitney services and to permit consolidation of fragmented taxi franchise areas. Allowing existing taxi systems to provide a full range of para-transit services could avoid large capital investments in new dial-a-ride vehicles (113).

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*A more detailed description and evaluation of these constraints, and specific recommendations on deregulation and changes in labor practices, may be found in INTERPLAN's study, Potential for Flexicab Services in Urban Transportation (145).

While the labor protection provisions of Section 13(c) of the Urban Mass Transportation Act do not require private para-transit (taxicab) operators to hire union labor or raise wages, the acceptance of these provisions by the operator in order to receive federal aid in effect improves the chances that taxicab company employees can later negotiate higher wages. Therefore, the 13(c) provisions may discourage some private cab companies from applying for aid, if they are not willing to relinquish the cost advantage of using relatively unprotected labor. In recent years, many taxi operators have even been discontinuing earlier wage and commission arrangements with their drivers and have begun to lease vehicles to drivers under specific conditions regarding dispatching and maintenance arrangements. The driver is free to operate as a private entrepreneur in seeking patronage, the operator is relieved of minimum wage problems, and driver productivity has increased (164, summary vol., p. 13). It may not be possible for the operator to enjoy these advantages of less restrictive labor practices if he wishes to receive federal aid. According to one source, the federal dial-a-ride experiment in Haddonfield used small buses and employed union bus drivers largely because of the Section 13(c) provisions, when taxicabs might have been a better choice on efficiency grounds (164, p. 16).

For the same reasons, the operator's acceptance of the 13(c) provisions may also indirectly raise para-transit fares or subsidy requirements, if the operating cost increase due to employee wage gains is not offset by savings in other areas. However, since the intention of the 13(c) provisions is to protect employees' rights, and there is as yet little evidence regarding the impact of these provisions on para-transit costs, removal of the 13(c) clause for private para-transit operators would have to be justified by showing that the benefits to the public of this exemption are greater than the loss to employees of federally supported labor protection.

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*Under the 1974 NMT Act, UMTA will be encouraging applications for federal aid by both public and private para-transit operators. See Note, p. ii.

ENCOURAGE PEDESTRIAN AND BICYCLE MODES (1.4)

Provide Pedestrian and Bicycle Facilities (1.4.1, 1.4.2)

EXPERIENCE. While it is generally accepted that Americans do little walking or biking and regard these activities more as a form of recreation or exercise than of locomotion, INTERPLAN found little data on the prevalence of these modes in urban transportation. Data taken from the 1970 census indicates that nearly 7 percent of urbanized area work trips, or 3.1 million trips a day, are made by foot, which is less than one-tenth the number made by car but twice as many as are made by rapid rail systems (360); see table below. This indicates that walking is already a popular means of getting to work, at present more popular than biking, which probably makes up a large part of the "other means" category in the table.

Table 1-12. Daily number and percent of urbanized area work trips by mode (1970).

	Trips (000)	Percent of total
Private auto, driver	30,169	65
Private auto, passenger	5,152	11
Bus or streetcar	3,993	9
Subway or elevated train	1,757	4
Railroad	463	1
Taxi	195	--
Walked only	3,139	7
Other means	803	2
Worked at home	825	2
TOTAL*	46,496	100

*Totals may not add because of rounding.

Source: Reference 360

The number of trips now made by car which used to be made by foot is not known, but it is generally accepted that pedestrian travel is declining. A downtown pedestrian survey made in Los Angeles in 1974 indicated a 30 per-

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cent drop in pedestrian traffic, attributed to the change in the function of the downtown area from a retail center to an office center. Photographs taken in 1923 and 1958 indicate half as many persons at a major downtown intersection in the latter year (115). An earlier survey of pedestrian travel characteristics in southwest Washington, D.C. analyzed data on walking trips as a function of age, sex, trip purpose, and day of the week for use in transportation and community planning, but this data is of little use in estimating the potential reductions in auto travel from encouraging pedestrian travel. One finding of the survey is important, however: nearly all pedestrian shopping, personal business, and other non-work trips were less than a mile long, while only about a third of the work trips were less than a mile, and 64 percent were between 1 and 2-1/4 miles long (187, p. 17). National data from the Nationwide Personal Transportation Study presented for comparison in the same article indicates that the Washington data is atypical; 71 percent of the persons walking to work walked 1/2 mile or less, with 99 percent walking 2 miles or less (187, p. 19). In any case, these figures give us an idea in what range short auto trips might conceivably be substituted by walking, should adequate facilities be provided and motivation to walk stimulated. INTERPLAN found no comparable data for bicycling; it is suspected that trips would be longer but frequency of use of this mode would be less.

It is often commented that Americans should be urged to emulate the greater use of bicycles and walking observed in European cities. Without more information than is currently available, it is impossible to evaluate this argument. Certainly there are differences in travel mode choice, but it is debatable to what extent the greater use of bikes and walkways in Europe depends on the street pattern, overall urban form, and availability of auto and transit modes. Differences between American and European cities could easily negate any transferal of experience. Whether such transferal is wishful thinking or an attainable goal could best be determined by an in-depth study of the applicability of European pedestrian and bike travel experience to American cities.

IMPACT ON GOALS. The potential impact of increasing walking and biking is limited by the percent of trips short enough to be suited to these modes.

Most urban car trips are in fact short enough to be substituted and do contribute significantly to urban VMT. Data from the most recent Nationwide Personal Transportation Survey cited in a recent Transportation Systems Center report indicate that 25 percent of auto trips are less than 1.5 miles long, and another 13 percent are between 1.5 and 2.5 miles. These trips account for only 4.8 percent of VMT and 3.2 percent of transportation energy (254, p. A-9-1). But another 25 percent of trips are from 2.5 to 5.5 miles long, accounting for another 10.9 percent of VMT and 7 percent of total transportation energy. If all trips below 5.5 miles were diverted to walking (0-1.5 miles) and biking (1.5-5.5 miles), the fuel and VMT reductions could be significant: 17 percent VMT reduction and 10 percent transportation energy savings.

But this is an unrealistic target. If only enough of these trips were diverted to save 0.45 percent of the total transportation fuel (509 million gallons a year), the present value of the recurring savings would be $1.7 billion (assumes a gasoline price of 40¢/gallon) (254, p. 11-3). Looked at from a cost-benefit point of view, therefore, the cost of building bike and pedestrianways can easily be justified with even these very modest assumptions about diversion from autos; this $1.7 billion savings over time would be enough to build a 70,000 mile network of bikeways in urban areas ($1 billion) and to go a long ways towards providing sidewalks in suburban areas, which could cost more than $1 billion (254, p. 11-3).

OVERALL EVALUATION. While encouraging pedestrian and bicycle modes may not be a major strategy in reducing congestion, air pollution, and energy use, its contribution need cost little and should have some impact. Many of the new walkers and bikers attracted by better right-of-way provisions will be making new trips rather than substituting for an auto trip, but some switchover should occur. Overall, encouraging walking could have a greater impact on VMT than encouraging biking, because more people accept walking than biking. The Washington, D.C. pedestrian survey found that about 60 percent of the pedestrians questioned felt either "very favorable" or "favorable" towards bicycling for short trips (187, p. 18); it is not known what percent of auto drivers or transit riders would favor bike riding or would find it practical for physical, weather and terrain reasons.

However, a relatively smaller switch to biking could have the same impact on VMT as a larger switch to walking, because it is suspected that biking trips are at least twice as long as walking trips. For this reason, it may be worth investigating the introduction in the U.S. of the motorized bicycle, popularly called a "moped" in Europe, which can be powered by a very small motor when going up hills and then switched back to pedal-power on level ground. This vehicle is not a small scooter or motorcycle but an adapted bicycle which could make bike riding comfortable for a wider range of travelers, since it makes far lower physical demands on the rider than a completely person-powered vehicle.

Encouraging these modes may be less important as a strategy by itself than as a component of two other strategies: attracting transit ridership (1.2) and restricting zonal access (3.3). Safe, attractive, clearly-labeled pedestrian access to rapid transit stations, bus stops, and intermodal transfer points (park-and-ride lots), and bike security and transport facilities should not be overlooked as part of a comprehensive program to improve transit service and promote transit's image. Bike racks at stations and in buses, and sidewalks, escalators, and special crossings near transit stops may not in themselves attract many riders, but their absence may discourage potential patrons. The addition of such facilities certainly has a favorable marketing impact for transit, particularly in Western cities where pleasant weather encourages walking and in cities with college campuses where bikes are widely used. A bike trailer is being used to tow bikes behind a bus running from the university to downtown in Santa Barbara (Santa Barbara News-Press, 1 September 1974), and two "Pedal Hopper" buses are in operation in Oakland to carry bikers and bikes to a favorite recreation spot (PT, 6/14/74). A full-scale network of commuter and recreational bicycle trails has recently been proposed for the Bay Area to increase the use of bikes as feeders to BART and Bay Area bus systems.*

Some improvement of streets and sidewalks is also important to the success of vehicle-free zones (also called pedestrian areas by some authors), in order to overcome the pedestrian's hesitancy to walk in the street even when cars are banned, and to make the area attractive to shoppers.

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*See BART/TRAILS: Bicycling, Riding, Hiking; A Study of the Commuter and Recreational Trail Potential to the Bay Area Rapid Transit System, prepared by Hart, Krivatsy, Stubee in association with Robert Conradt and Michael Painter & Associates for the U.S. Department of Transportation, Office of the Assistant Secretary for Environment, Safety and Consumer Affairs, San Francisco, February 1974.

The overall importance of encouraging biking and walking, then, is as a minor auxiliary strategy to the transit and para-transit strategies for increasing the use of non-auto modes, and as a required element for programs to attract transit ridership and restrict auto access.

SECTION 2
IMPROVED VEHICULAR FLOW (2.0)

INTRODUCTION

The strategies which promote vehicular flow contribute to urban mobility in the way most directly grasped by the greatest number of urban travelers: by making it easier to drive. The first and last strategies are the ones which directly affect most drivers—increasing vehicle throughput (2.1) and reducing peak-hour traffic volumes (2.4)—while the other two strategies focus on special congestion problems, those caused by goods movements (2.2), which occur primarily in retail or manufacturing districts, and those occurring at large airports (2.3).

Since these four strategies have generally been applied with the intention of reducing congestion alone, little data has been gathered on the impacts of these strategies on the other two goals of this study, air quality and energy conservation. However, the widespread acceptance of some of the recommended actions, such as extending and improving roadways (2.1.1) and improving traffic control (2.1.2), as well as the considerable interest of EPA in traffic control and dedicated transit and carpool lanes (2.1.4) as transportation controls, make it important that we examine the impacts of these actions in particular and of the four strategies in general. In any case, we want to know if their application purely as congestion-reducing measures would have any adverse effects on air quality or energy consumption.

INCREASE VEHICLE THROUGHPUT (2.1)

This strategy includes the most traditional of actions considered in this document (extend and improve roadways and initiate traffic controls) and two actions which are extensions of conventional traffic control techniques (ramp metering and dedicated lanes). More money has been spent on the traditional approaches to mobility—road building and traffic controls—than on any other action covered in this document, and the evidence is more widespread and familiar than that of any other action.

With one exception—extend and improve roadways—the actions which make up this strategy are directed at making more efficient use of existing road facilities: moving more vehicles and more people over the same facilities in less time. Traffic control focuses primarily on moving more vehicles; ramp metering (2.1.3), while essentially a traffic control (vehicle-oriented) measure, can also be used to give preferential treatment to high-occupancy transit or carpool vehicles.

Extend and Improve Roadways (2.1.1)

EXPERIENCE. Since the 1920s, the American way of providing greater individual mobility and preventing roadway congestion has been to build more roads and to extend and improve the existing roadway systems. As early as 1914 there were more than one million Model T Fords; by 1923 annual production of the Model T had reached one million, accounting at that time for about 50 percent of the automobile market.* These new road vehicles had to be supplied with roads to ride on. After a relatively slow start in the 1920s, the road-building pace accelerated in the 1930s and 1940s. In the next two decades (1950-1970), while the net annual increase in the number of automobiles reached a level of nearly 5 million, some $375 billion was spent on municipal and rural roadway systems, the municipal systems accounting for $100 billion (see Table 6, p. 23, Volume 4). The physical magnitude of this undertaking can be judged by noting that in 1921 there were 450,000 miles of surfaced roadways in the U.S.; by 1971 this figure had grown almost tenfold to some 4,000,000 miles,

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*William J. Abernathy and Kenneth Wayne, "Limits of the Learning Curve," Harvard Business Review, September-October 1974, p. 112 (Exhibit II, The Ford Experience Curve).

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the equivalent of adding over 65,000 miles of new surfaced roadway to the roadway system in each of the 50 years. Of the total mileage, some 600,000 miles are now in municipalities, a ratio of one urban mile to about five rural miles.

This feat of construction and the accompanying increase in auto ownership provided Americans with individual mobility unmatched anywhere in the world. The sheer magnitude of the national effort involved in building and improving these roadways, as well as in manufacturing, maintaining, and fueling the automobiles which use them, and the momentum generated over the last five decades, make it inevitable that roadway construction will go on, irrespective of its undesirable side effects. It is for this reason that INTERPLAN feels that the extension and improvement of roadways must be regarded as a major means of improving mobility.

However, the deterioration in the quality of urban life resulting from this huge construction effort created pressures to decelerate the seemingly endless expansion of roadways in the 1960s and 1970s. For instance, in 1959 the Los Angeles region had an approved 1980 plan for a 1,557-mile network of freeways designed to assure that no neighborhood was more than four miles from a freeway.* Between 1965 and 1974, 118 miles were deleted from this network by the state legislature as a result of opposition from neighborhood groups and antifreeway forces, reducing the planned freeway system to 1,439 miles. Sections of even this reduced network are still being challenged, and may eventually be deleted. Having nearly achieved the "ideal" system—the Los Angeles network, with 23 fully or partially completed freeways, is the largest urban freeway system in the world—the city and its people have revolted against it. The existing web of freeways, built at a total cost of $3 billion, and the freeway routes deleted due to the above-mentioned opposition, as well as routes involved in litigation and therefore most unlikely to be built, are shown in Figure 2-1.

Similar opposition to urban freeways has been experienced in most urban areas: San Francisco wants its half-completed Embarcadero Freeway pulled down; Seattle successfully defeated plans to construct bridges across the bay and develop the connecting road network; and Philadelphia is in the throes of legislative action aimed at curtailing the planned expansion of its roadways, including an airport access freeway.

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*The Los Angeles highway story is based on an article by Ray Herbert, "Southland's Freeway Program Slowly Dying", Los Angeles Times, 11 March 1973.

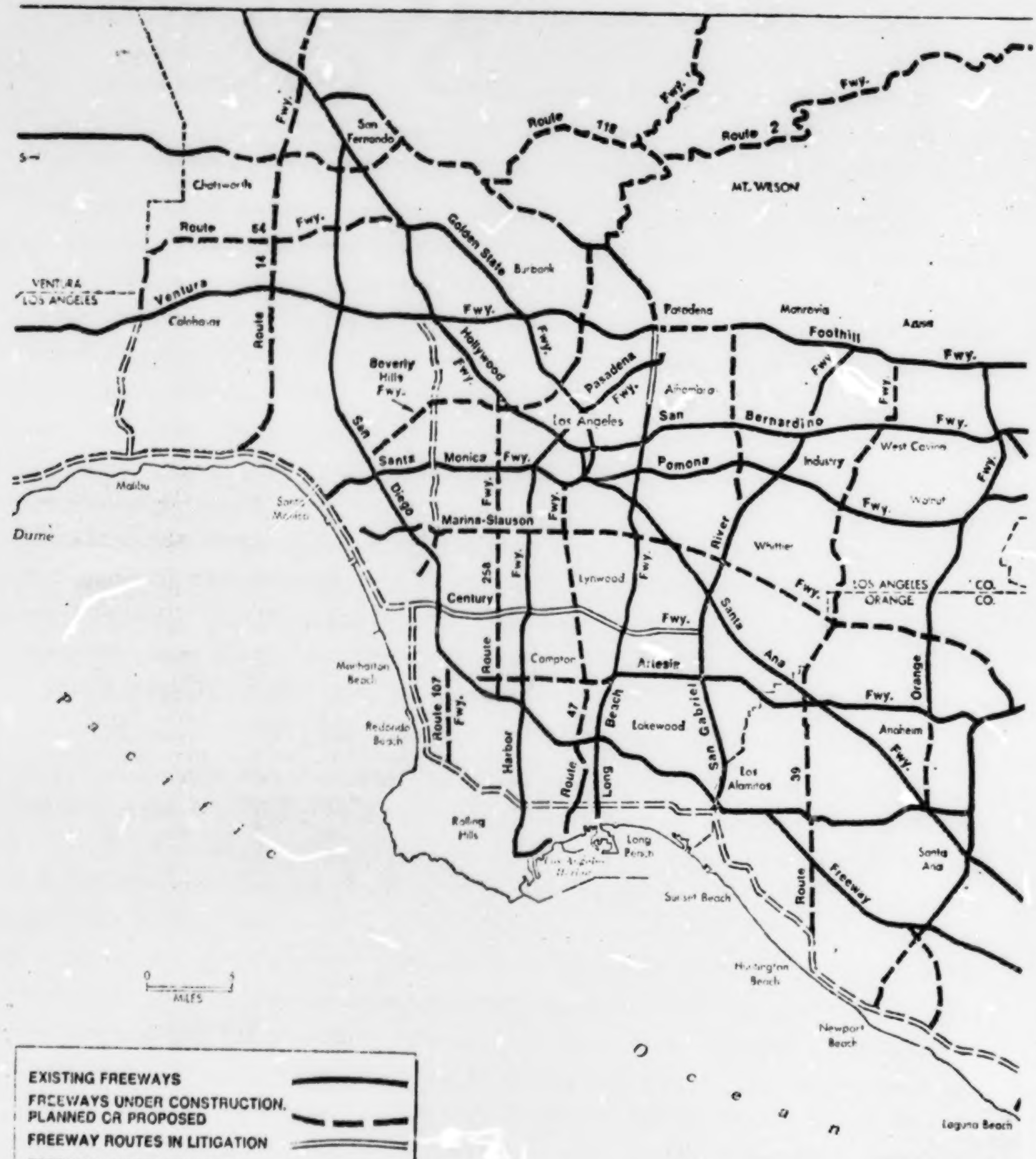

Figure 2-1. Los Angeles freeway network, 1974.

Source: Ray Herbert, "Southland's Freeway Program Slowly Dying," Los Angeles Times, 11 March 1973 (map by Patrick Lynch).

IMPACTS ON GOALS. The three main drawbacks of continuing roadway construction are:

1. Its inability to absorb traffic congestion during peak traffic hours.
2. Its characteristics as a generator of air pollution.
3. Its indirect stimulus to further increase transportation fuel consumption.

Congestion. As discussed in Volume 4, a service level of 35 to 40 mph or higher is now accepted as the minimum for freeways and expressways (see 142, p. 25). By this standard, in urban areas 20 percent of the freeways, 23 percent of the principal surface arterials, and 11 percent of the minor arterials now experience unacceptable service levels for some 3 to 5 hours every weekday. Alleviating this somewhat unsatisfactory status by further highway construction, according to the 1972 National Highway Needs Report (298), will cost some $200 billion between 1968 and 1990, and the total mileage of urban roadways will have to be increased from roughly 600,000 to 800,000. These expenditures and the resultant increases in urban road mileage are expected to bring traffic flows to acceptable service levels, but only if the report's assumptions on the increase of vehicular traffic between now and 1990 are fulfilled. These assumptions are that the historic 4.2 percent annual growth in vehicle miles traveled experienced from 1950 to 1970 will be slowed, and that transit ridership will increase by 1990 to 10 billion trips per year.

These assumptions do not appear to be supported by past experience. It has often been observed that building roadways induces travel.* The oft-cited case of Chicago's Congress Street Expressway is described in Reference 133 (p. 3-20). "The study (a 'Before' and 'After' [1959 and 1961] examination of the traffic within a 16-square mile area around the expressway) noted that there was a 21 percent increase in total vehicle-miles of travel within the study area over the two-year period—an annual rate of increase which was three times the normal Chicago increase of 3.5 percent a year or 7 percent for the two-year period under study. ... There was a growth of about 14 percent [in VMT] over what was considered normal for Chicago based on traffic counts made in 1953, 1956 and 1959. Although a part of this 14 percent difference was probably traffic attracted from outside the study area, some of the increase was doubtless due to 'induced' travel which would not have occurred in the absence of highway improvements."

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*See Volume 2, pp. 49-51 for an account of New York City's experience with its new bridges and freeways.

These traffic increases did not always, however, result in a deterioration in service levels. A careful evaluation of the Chicago expressway's effect on volume-to-design-capacity ratios* notes that traffic on two of the eight arterials intersecting the expressway increased to the point where the volume-to-design-capacity ratio exceeded 1 (another of the 8 arterials already had a ratio greater than 1).** At the same time, however, volume-to-design-capacity ratio on ten of the 11 east-west (parallel) arterials declined. Whereas in 1959 all 11 had peak-hour ratios greater than 1, in 1961 only three did, and only one had a ratio greater in 1961 than in 1959, despite the increases in area traffic. Furthermore, traffic volume on local streets decreased by 7 percent. Similar experiences are cited for Los Angeles and Boston (196, pp. 75-76, 80-81). Therefore, in the short run, freeway construction does reduce overall system congestion, at least in some cases.

In conclusion, while highway construction and improvement will undoubtedly remain a major means of increasing mobility, it tends to stimulate further demand, eventually recreating the congested conditions which it was intended to alleviate. Once an urban road network has developed to the point where its geographic coverage is adequate for purposes of mobility, additional building simply to increase capacity of those routes (including building parallel routes) is likely to be limited beyond some politically determined point. This point will occur whenever the perceived disruption of the urban environment, particularly in terms of land use, takes on a greater value to the community than the improvements in speed or time savings that more road capacity could offer. Beyond this point, other means of increasing capacity will be demanded and used. For these reasons, INTERPLAN does not consider a roadway building program by itself as the best long-run approach to dealing with urban traffic congestion.

Air Quality. Reference 243 estimates that motor vehicles contribute approximately 44 percent of the total air pollution on a nationwide basis. In urban areas, 65 percent of CO, 46 percent of HC and 37 percent of NO_x are due to the 100 million motor vehicles which run on 600,000 miles of urban roadways.

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*Design capacity is defined as that capacity which will provide for travel "without undue delay or congestion" at the particular level of projected volume (196, p. 78).

**Frederick F. Frye, "The Effect of an Expressway on the Distribution of Traffic and Accidents" (Chicago Area Transportation Study Publication 66,549, mimeographed), presented at the 42nd Annual Meeting of the Highway Research Board, Washington, D.C., January 1963, cited in Meyer, Kain, and Wohl (196) pp. 77-80.

If the forecast of the Highway Needs Report is to be believed, the total mileage of urban roadways will have to increase to a total of about 800,000 miles in order to accommodate the 20 to 30 million urban vehicles which will be added by auto manufacturers to the existing urban fleet between now and 1990.

At first sight, the effect of such increases on air quality standards would appear to be disastrous. However, depending on EPA's success in implementing the vehicle emission standards required by the Clean Air Act, emissions from autos in urban areas could be much lower in 1990 than in 1970. As Figures 9, 10 and 11 in Volume 4 show (see Section 2, pp. 53-54), only if the 1974 standards were retained indefinitely would vehicle emissions eventually surpass the pre-1970 high. If the 1975 interim standards (15 g/mile for CO; 1.5 g/mile for HC; 0.2 g/mile for NO_x) are implemented, vehicle emissions would fall to less than half that level by 1990, with the attrition of pre-1974 autos. As shown in Tables 18 to 23 in Volume 4 (see pp. 49-51), the ambient air quality standards will be met in many cities before 1985, and in some areas much sooner. More difficult cases are represented by Los Angeles and, to a lesser extent, Chicago. In areas such as these, the continuing expansion of roadways should be, and is being, opposed on the grounds of air quality standards. In most other areas, cleaner engines alone could do the job if the time deadline were postponed several years.

Energy Consumption. As mentioned above, the more roadways that are built, the more vehicular traffic will be induced to use them. Thus it would appear that present planned urban roadway construction is a direct inducement to the consumption of more gasoline and diesel fuels. Indeed, the Department of Interior forecasts a 130 percent increase in U.S. petroleum consumption between 1971 and the year 2000, and a 65 percent increase in urban auto petroleum consumption (see Table 31, Section 2, Volume 4, p. 67). This increase in urban auto petroleum consumption may be traced to three trends:

1. Relatively more VMT will be traveled by the current stock of cars and their replacements as the trend to longer trips and higher annual mileage continues.
2. Additional VMT will be traveled by cars to be added to the current stock.
3. Fuel requirements of new vehicles could increase if 1976 emission standards are enforced before manufacturers can mass produce engines that are both clean and fuel efficient.

In other words, there is a direct conflict between more roadway construction and more stringent emission standards on the one hand, and conservation of petroleum on the other. If a national energy conservation policy is adopted in 1975, such a policy should imply not only a delay of air quality deadlines but also a cut in planned roadway construction.

OVERALL EVALUATION. The automobile industry and road improvement programs associated with auto use jointly account for a significant fraction of the nation's economic activity. Some 4 million people are employed in auto-connected industries, 1,500,000 in auto manufacturing and 2,500,000 in auto and gas retailing and auto servicing. In addition, some 100,000 people are directly involved in road construction and maintenance, not counting the employees of plants making concrete, road construction machinery, and other equipment and supplies. Several hundreds of thousands more are employed in the auto supply industries such as steel and rubber manufacturing and power generation. The total number of jobs controlled by the "highway lobby", directly and indirectly, approaches 10 million, or one-eighth of the total labor force in the U.S. With the national level of unemployment already close to 7 percent and the militant attitude of the labor unions, there is no question of threatening this labor force with cutbacks in the auto-highway sector.*

Furthermore, nearly every American presently benefits from the present auto-highway system and would be directly affected by a reversal of auto-oriented policy. There are enough automobiles in the country to give everybody a front seat and enough roads to carry them: on an average, 25 cars for every mile of roadway. In spite of a worldwide shortage of reasonably priced petroleum, the cost of gasoline in the U.S. continues to be among the lowest in the world, and the FEA is doing everything in its power to prevent an acute absolute shortage, at least before the end of this century.

Until recently, any group opposed to the auto-oil-FHWA interests could hardly hope to compete with their economic and political power. The transit industry, for example, hardly constitutes a powerful lobby, with but 140,000 employees, 6 million riders, and a $750 million deficit. Yet the political tide has begun to turn, as witnessed by the inclusion in the 1973 Federal Aid

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*However, as Volume 2 of this study shows, the maximum diversion of urban travel from auto to transit by 1990 (43 percent modal split in 1990) could create close to 2 million new transit jobs, many of which could be filled from the present ranks of the auto service industry.

Highway Act of provisions for the transfer of interstate highway construction funds and federal-aid urban system funds to public transit projects at the request of states and municipalities (see p. 1-4 above). While no short-term dramatic changes can reasonably be expected, the precedent has been set to divert highway funds to mass transit and to consider the long-range alternatives to continued auto-freeway growth.

Therefore, strategies to improve auto alternatives and urban air quality, as well as those aimed at conserving petroleum, must go hand-in-hand with measures to efficiently utilize and intelligently extend and improve roadways. It will be crucial to the attainment of the three goals—mobility, air quality, and energy conservation—that the right balance be found between the deceleration of the present pace of roadway construction and the expansion of mass transit facilities. Under the new legislation, it will be up to local authorities to decide to what extent they want to effect this shift. The central administration (DOT) has largely abandoned its central planning and decision-making prerogatives.

Whatever extensions and improvements are in the end made to the urban roadway system, they should anticipate future methods for more efficient use of the space now devoted to urban roadways. The two most important actions recommended by INTERPLAN are: (1) to leave sufficient rights-of-way (in the median or shoulder allowance, for example) for new, not yet clearly defined, transportation uses, most likely some form of rail transit or dual-mode system*; and (2) to examine the need to provide electronic guidance and possibly propulsive power under existing and new roadways for PRT or dual-mode systems.

Initiate Traffic Control Improvements (2.1.2)

EXPERIENCE. Urban transportation projects which are usually lumped together as traffic control or traffic flow improvements include:

- sophisticated traffic-responsive signal systems and signal synchronization
- on-street parking restrictions, general or by time of day
- lane widening
- turn-lane additions
- channelization of traffic

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*Other INTERPLAN reports on rail systems (141) and transit integration (136) suggest areas where relatively small investments and minor modifications can result in the greatest benefits; dual mode is discussed in Volume 3 (144b).

- implementation of one-way streets
- driver advisories
- reversible lanes
- elimination of bottlenecks
- bus and truck turnouts for loading and unloading.

Most of these projects require minimum right-of-way acquisition or new roadway construction. Improvements at intersections are usually considered especially important, since it is generally accepted that the capacity of an intersection to process traffic determines the capacity of the roadway.

Most of the above improvements fall in the category of projects which have been carried out in recent years under the TOPICS program (Traffic Operations to Increase Capacity and Safety). This program, established in 1968, is administered by the U.S. Department of Transportation, Federal Highway Administration. It was initiated to reduce traffic congestion and was designed to obtain the maximum efficiency and capacity from the existing urban street network with a minimum of expenditure. Under TOPICS, federal funds are matched with local funds on a 50:50 basis to complete traffic flow improvement projects in urban areas. As of mid-1972, TOPICS had obligated approximately $270 million for planning and construction; 270 construction projects had been completed, and 1,100 additional projects had been authorized for funding.

Generally speaking, traffic control improvements are considered relatively inexpensive and cost-effective, since user benefits from travel time savings and, often, accident reduction, usually far outweigh the costs of the improvements. Even such an "inexpensive" strategy, however, can involve large amounts of money, especially when improvements such as an area-wide traffic signal interconnect system are contemplated. As Table 2-1 indicates, the estimated cost for an automated traffic signal interconnect system for the entire South Coast Air Basin (Los Angeles) is $60 million (180, p. 7); federal funds needed for TOPICS projects from 1970 to 1990 are (316):

Urbanized areas	-	$1,897 million
Small urban areas	-	342 million
Total	-	$2,239 million

or $112 million per year. The actual cost of TOPICS projects would be double that amount since localities must furnish equal matching funds.

There is no doubt that traffic flow improvement projects can have significant impacts on traffic flow by increasing average speeds, reducing travel time, and reducing the number of stop-and-go driving cycles, which is especially important from the point of view of air pollution and energy consumption (see below, pp. 2-20 - 2-26). Traffic signal synchronization or traffic-responsive signal systems seem to have the most dramatic effects. Reference 6 gives the following initial travel time decreases on affected roads resulting from improved signal systems in various cities (p. A-8):

	Percent decrease in travel time
U.S. Cities:	
Kansas City	12
Louisville	1 - 24
New York	20 - 40
San Jose	10 - 12
European Cities:	
Glasgow	12
London	9

The results of these and other types of projects are summarized in Table 2-1. Representative of these results is a 1971 statistical study of the effect of traffic flow improvements on travel speed at 14 locations in Newark and Louisville described in Reference 133 (p. 3-25 ff.). This study showed a mean increase in speed from 13.6 mph to 17.3 mph, an average improvement of 26%. The range of expected improvements in speed from traffic flow improvements was 10-40 percent, although there are many values which fall above and below this range. One of the Newark projects showed a 121.6 percent increase in speed (from 7.4 mph to 16.4 mph) in the predominant direction of flow, while another showed only a 4.6 percent increase. The 10-40 percent range in speed increase found in this study encompasses all the examples reported on in Table 2-1.

While most of the improvement techniques listed above have been in use for several years and have proved effective, the technique of providing driver advisories and displays has had very limited testing to date, and appears to be of negligible value in the places where it is in operation. According to Reference 239, driver advisories have been implemented only in conjunction with ramp metering, making it difficult to assess the impact of driver advisories alone. This reference states that such systems have failed to indicate any substantial benefits, and that surveys have shown that many drivers fail to

Table 2-1. Documented impact of strategies and actions on offsetting phenomena: Initiate Traffic Control Improvements (2.1.2).

PHENOMENA						COST ESTIMATES	
1.0 Improved Auto Alternatives	2.0 Improved Vehicular Flow	3.0 Reduced Urban Auto Use	4.0 Reduced Urban Travel Demand	5.0 Reduced Vehicular Air Pollutant Emissions	6.0 Reduced Vehicular Petroleum Consumption	Highway, Auto	Rail, Bus & Para-Transit
Reference 239 Not mentioned.	Amount of travel time reduction is directly proportional to the degree of prior deterioration of the street system (p. 61). Signal progression may result in as much as a 40% increase in peak-hour speeds, and a 60-70% reduction in number of traffic delays (p.62).	Not mentioned.	Not mentioned.	Automobiles moving at steady speeds of 30-35 mph produce minimum air pollution; no figures (p. 62).	Only calculated in terms of auto user savings; see next column.	Auto users would save money by reduced gasoline consumption: eliminating one stop along a route would save approximately .11 cents in fuel consumption (at 54¢/gal.) while increasing speed from 10 mph to 20 mph would save approximately .13 cents per mile (p. 59). Costs for installing new traffic signals range from $2,000 (for simple signals) to $35,000 (for complex traffic responsive systems) (p. 61).	Not mentioned.
Reference 7 Not mentioned.	Typically, installation of progressive signal systems might increase overall speeds from 20 mph to 30 mph (p. 3-13). Results of a traffic responsive signal system in Wichita Falls, Texas: 16.3% reduction in vehicle stops; 31.1% reduction in average vehicle delays; and an increase in average peak-hour speeds from 20 mph to over 30 mph (p. 3-16).	Reduced congestion may induce more, longer, and more dispersed trips unless concomitant measures are taken to reduce the number and length of trips (p. 3-5).	Could increase; see Reduced Auto Use (3.0).	If more and longer trips are induced as a result of traffic improvements, it would result in greater amounts of pollutants spread over a wider area (p. 3-5).	Not mentioned.	Not mentioned.	Not mentioned.

Table 2-1. (continued)

PHENOMENA						COST ESTIMATES	
1.0 Improved Auto Alternatives	2.0 Improved Vehicular Flow	3.0 Reduced Urban Auto Use	4.0 Reduced Urban Travel Demand	5.0 Reduced Vehicular Air Pollutant Emissions	6.0 Reduced Vehicular Petroleum Consumption	Highway, Auto	Rail, Bus & Para-Transit
Reference 29 Not mentioned.	No figures.	Possible counter-effect of induced traffic due to eased flow may result in some localities, but an overall increase in travel would seem unlikely (p. 8).	Not mentioned.	Not mentioned.	If a 50% reduction in the number of accelerations can be obtained, an energy savings of about 10% for urban driving can be achieved. This would mean an annual savings of 2 billion gals. of gasoline, or 91 million barrels of crude petroleum (p. 4).	Not mentioned.	Not mentioned.
Reference 180 Not mentioned.	Uniform traffic control program for Los Angeles area could save motorists 42 million hours annually (p. 6). Automated traffic signal interconnect system for Los Angeles County could improve highway mobility by 15% and save motorists over 10 million hours annually (p. 7).	Not mentioned.	Not mentioned.	Uniform traffic control program for Los Angeles area could result in approximately a 3% reduction in pollution (p. 6). Automated traffic signal interconnect system for Los Angeles County estimated to reduce pollution 1% (p. 7).	Uniform traffic control program for Los Angeles area could save 85 million gals. of gasoline annually (p. 6). Automated traffic signal interconnect system for Los Angeles County could conserve 21 million gals. of gasoline annually (p. 7).	Estimated cost of uniform traffic control program for the Los Angeles area: $42.7 million (covers 1,826 miles of streets), (p. 6). Estimated cost of automated traffic signal interconnect system (for entire South Coast Air Basin): $60.4 million (p. 7).	Not mentioned.

Table 2-1. (continued)

PHENOMENA						COST ESTIMATES	
1.0 Improved Auto Alternatives	2.0 Improved Vehicular Flow	3.0 Reduced Urban Auto Use	4.0 Reduced Urban Travel Demand	5.0 Reduced Vehicular Air Pollutant Emissions	6.0 Reduced Vehicular Petroleum Consumption	Highway, Auto	Rail, Bus & Para-Transit
Reference 6							
Not mentioned.	Improved signal systems in effect in several cities have resulted in an average 5-15% improvement in travel time, an average 10-30% reduction in stop and go cycles, and a 2-6 mph speed increase (p. A-8).	Traffic flow improvements may have a long-term effect of increasing VMT unless non-automobile modes of travel are simultaneously implemented (p. A-7).	Not mentioned.	Should decrease air pollution; no figures (p. 17).	Regional energy reduction from improved signal systems: 1-4%; from one-way streets, reversible lanes, and no on-street parking: 1-4%; from widening intersections: 0-1%; from eliminating unnecessary traffic control devices: 0-2% (p. 17). (Note: the elimination of one unwarranted traffic signal would save 5,000 KWH annually, in addition to the savings in fuel consumption from eliminating an unnecessary stop for traffic (p. A-9). Long-run effect may be increased VMT and energy consumption, if methods to encourage non-automobile travel modes are not implemented (p. A-7).	Not mentioned.	Not mentioned.

Table 2-1. (continued)

PHENOMENA						COST ESTIMATES	
1.0 Improved Auto Alternatives	2.0 Improved Vehicular Flow	3.0 Reduced Urban Auto Use	4.0 Reduced Urban Travel Demand	5.0 Reduced Vehicular Air Pollutant Emissions	6.0 Reduced Vehicular Petroleum Consumption	Highway, Auto	Rail, Bus & Para-Transit
Reference 316 Not mentioned.	Not mentioned.	Not mentioned.	Not mentioned.	Not mentioned.	Not mentioned.	Total U.S. needs for TOPICS funds, 1970-1990: urbanized areas, $1,897.27 million; small urban areas, $342.09 million; total, $2,239.36 million.	Not mentioned.
Reference 3 Not mentioned.	For Baltimore, a comprehensive traffic flow improvement program could yield speed increases of 5% on expressways and local streets and 15% on arterials, for an average 10% increase in speed (p. A-6).	Traffic flow improvements may act as a long-term stimulus to increase trip lengths and induce additional traffic (p. 23).	Could increase; see Reduced Urban Auto Use (3.0).	It is estimated that an area-wide traffic flow improvement program could reduce mobile source emissions 10% in Baltimore (p. 23) but only 2% in Boston (p. 36) because of Boston's less orderly street system.	Not mentioned.	Cost for traffic flow improvement program estimated at $7 million for Baltimore, with user benefits from travel time savings and accident reductions at $51.7 million (p. 24). Costs for Boston estimated at $9.5 million with user benefits at $14 million (p. 36). This strategy is thus evaluated as relatively cost-effective.	Not mentioned.

Table 2-1. (continued)

PHENOMENA						COST ESTIMATES	
1.0 Improved Auto Alternatives	2.0 Improved Vehicular Flow	3.0 Reduced Urban Auto Use	4.0 Reduced Urban Travel Demand	5.0 Reduced Vehicular Air Pollutant Emissions	6.0 Reduced Vehicular Petroleum Consumption	Highway, Auto	Rail, Bus & Para-Transit
Reference 133 No changes in modal mix (p.10).	Substantial potential for improving traffic flows in many cities. From results of traffic flow improvement programs in Newark and Louisville, an average increase in speed of 27% is calculated (p. 3-13).	Possible increase in trip generation as a result of improvements in traffic flow. To control traffic volumes, motor vehicle restraints would be required (p. 10). In most metropolitan areas, the additional capacity afforded by traffic flow improvements would be "used up" within 2 to 4 years because of higher vehicle volumes which would be attracted (p. 3-22).	Could increase; see Reduced Urban Auto Use (3.0).	Automobile emissions would actually increase if, after a few years, average vehicle speed dropped to pre-improvement level, but traffic volume increased (p. 3-32). For two hypothetical cases, absolute emissions decrease for only the year following implementation (17.6% reduction). For all subsequent years, emission levels would be higher than if no traffic flow techniques had been implemented; at the 5th year after implementation, emissions would be 19-24% greater than for the base year with no traffic flow improvements (p. D-6).	Not mentioned.	Investment required for a major traffic flow improvement program would be very large; for Los Angeles, plans for comprehensive traffic surveillance and control improvements call for a 10-year cost of about $120 million (p. 3-34).	Not mentioned.
Reference 124 Not mentioned.	No figures.	Improved traffic flows might result in increased vehicle volumes, VMT, and longer trip lengths (p. 14).	Could increase; see Reduced Urban Auto Use (3.0).	Traffic flow improvements overall would have a minor effect on air quality compared to other strategies (p. 14).	Not mentioned.	Not mentioned.	Not mentioned.

comprehend the signs fully, while even those who claim to understand the displays are often not guided by the information. A survey of the effect of driver advisories in Chicago concluded that "the informational signs do not have a measurable effect upon the daily distribution of expressway-bound traffic" (239, p. 257). Another study points out, however, that even though driver advisories might not have a major impact, by diverting even a small amount of traffic from roadways which are near congestion levels they may mean the difference between such roadways operating at stable flow rates or at forced flow rates (7, p. 3-8).

While the effects of most traffic control improvements seem very encouraging from a traffic engineering viewpoint, two mitigating factors must be taken into account when evaluating their impacts. Most importantly, there are many indications that gains in travel speed may be very short-lived, as they are soon offset by normal annual growth in VMT and by additional traffic attracted to the improved facility. Thus, in a few years, average speeds may decline to pre-improvement levels or lower, though the roadway may be carrying more vehicles per hour than before the improvements. Under such conditions, pollutant emissions and fuel consumption could be worse than if the improvements had never been made (see "Impacts on Goals" below, p. 2-23).

Another consideration which seems to be overlooked in some evaluations is the fact that traffic flow improvements at one point in the street network often result in traffic deterioration at another point or points. For instance, when a one-way street is implemented, speed will usually increase on that particular street, but this benefit may be outweighed by increased VMT (and thus increased air pollution and fuel consumption) resulting from route diversions around the one-way street. Therefore, the effect of traffic flow improvements should be evaluated over the entire street network, not merely at the point of improvement.

IMPACTS ON GOALS.

Congestion. Although experience with traffic control measures indicates that they can result in substantial traffic flow improvements, the duration and long-term impacts on congestion of these measures are the ultimate criteria of effectiveness. In most cities with traffic congestion problems, there is a latent demand for trips, especially during the peak hours, which will manifest itself in additional trips whenever new highway capacity is provided, whether through new construction or improved travel times on existing facilities (133, pp. 3-20, 3-21). Furthermore, longer and more dispersed trips will be generated, since it has also been established that increased travel speeds eventually tend to encourage motorists to make longer trips (133, p. 3-15).

There is some difference of opinion as to how rapidly increases in roadway capacity following traffic flow improvement programs are taken up with new traffic, i.e., how many years flow improvements continue before the facility returns to its pre-improvement level of congestion. Reference 197 mentions that traffic flow improvements may possibly be a long-term stimulus to longer trips and additional traffic, but states that such effects in the short term would be negligible (p. 25). Reference 7 cites statistics from a traffic management program in England (Gateshead) indicating that over a three-year period (1965-1968) traffic entering the area had increased 5 percent, and vehicle miles traveled within the area had increased 13 percent, but total vehicle hours traveled within the cordon had decreased 23 percent and speed had increased 37 percent (p. 3-19). These figures would seem to indicate that the improvements were still having an appreciable effect after a period of three years.

On the other hand, Reference 133, which contains the most detailed analysis of this problem, cites conflicting experience in several urban areas, including the fact that in New York City new tunnel and bridge facilities appear to be operating at capacity levels within 2 years of completion (p. 3-21). They conclude, "In most metropolitan areas, the additional capacity afforded by traffic flow improvements would tend to be 'used up' within two to four years because of the higher volumes which would be attracted" (p. 3-22).

This study also contains a modeling exercise which illustrates the impact of a traffic flow improvement program on speed and traffic volume over a five-year period, given the following assumptions:

- The facility is a typical urban arterial with a roadway capacity before improvements of approximately 1,500 vehicles per hour per lane for one-way direction; average vehicle speed is 15 mph.
- The improvements are a package of traffic flow techniques, consisting largely of improved signalization.

In the exercise, the base case, or Case 1, in which no traffic flow techniques are implemented, no induced traffic is assumed, and annual traffic growth is assumed to be 3 percent, is compared with two cases where these techniques are used:

- Case 2: Traffic flow improvements are implemented in year 1, resulting in an immediate 5 mph speed increase; induced traffic generated by the improvements occurs in year 2 and is anticipated to utilize, by the end of year 2, the capacity increase made possible by the traffic flow improvements; annual traffic growth is assumed to be 3 percent (same as in Case 1).
- Case 3: Traffic flow improvements and induced traffic rate assumed to be the same as in Case 2; annual traffic growth rate anticipated to decline from 3 percent to 1-1/2 percent as roadway capacity approaches saturation. (133, pp. D-3, D-4)

The results show that at the end of the fifth year, the average speed for Cases 1 and 2 would be 10 mph, but the total volume carried in Case 2 is 1,989 vehicles per lane per hour, compared to 1,739 under Case 1. In Case 3, speed would be 11 mph and total volume 1,922 in the fifth year.

Congestion, as measured by speed in mph, decreased in Cases 2 and 3 only for the year immediately following the improvements, although throughput had increased by about 10 percent. After five years, speeds were almost the same as if no improvements had been made.

Air Quality. Traffic flow improvements, though originally undertaken primarily as a means of reducing congestion, are now often viewed as a useful method for reducing pollutant emissions and fuel consumption as well. The reason for this is that, up to a certain point, fuel consumption rates and CO and HC emission rates decrease as speed increases, although NO_x emissions appear either to increase somewhat or to be unaffected by speed. Furthermore, both fuel consumption and emissions are lowered by a reduction in the number of stop-start or acceleration-deceleration cycles and in the amount of time spent idling. Figure 2-2, reproduced from Volume 4 (142, Figure 28, p. 103), shows that for tested steady state speeds, HC emissions change very little, dropping off slightly as speed is increased to 30 and 40 mph, and then increasing slightly as speed is further increased to 70 mph. CO averages drop about 40 percent as speed is increased to 30 mph, then increase to over twice the original value as speed is increased to 70 mph. Emissions were also monitored for average speeds, represented a 7-mode procedure which included idle, acceleration,

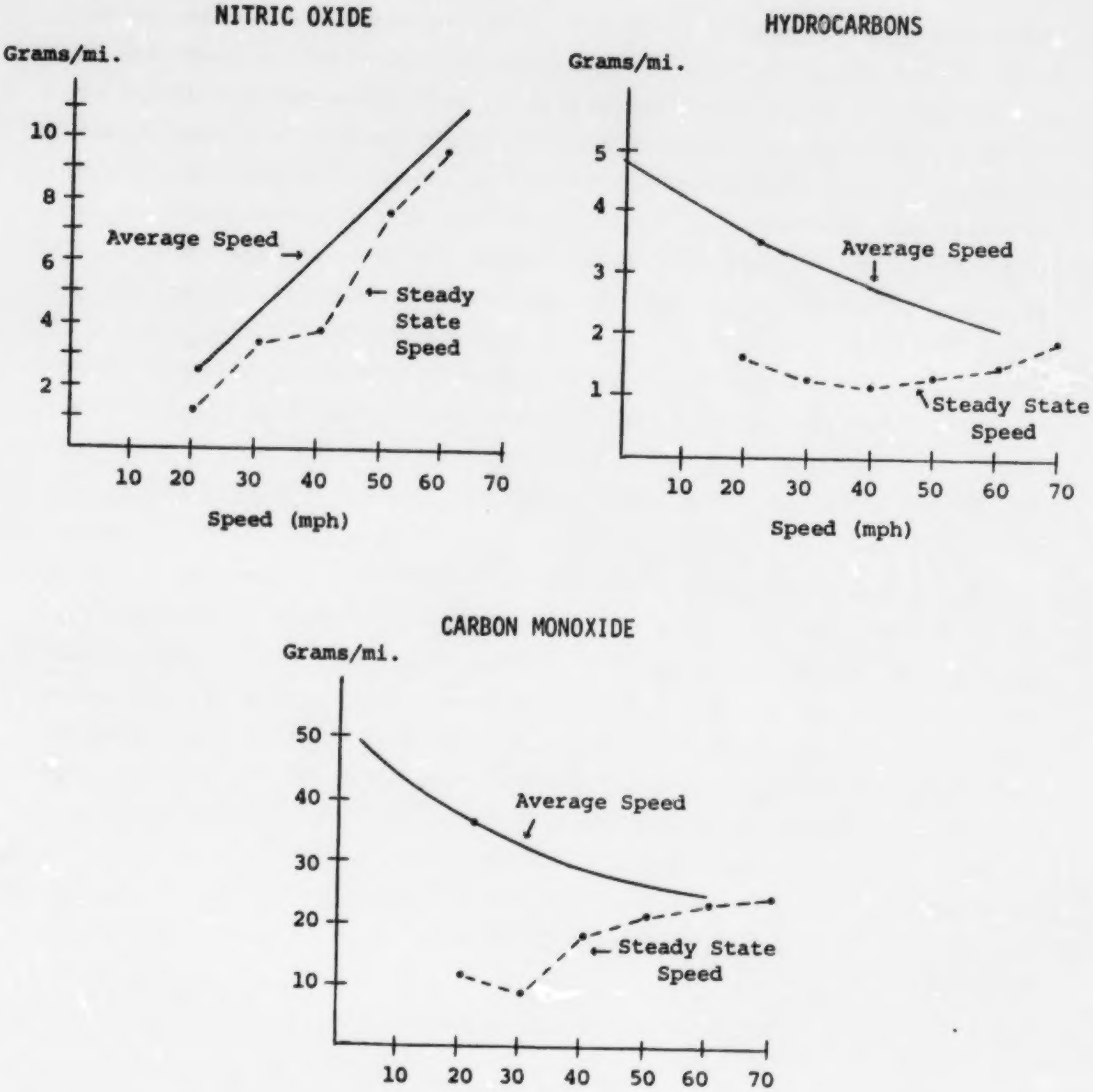


Figure 2-2. Emissions of NO_x, HC, and CO as a function of speed.

Source: Reference 43. Results based on tests of three cars: (1) 1970 Chev. – 350 in^3; (2) 1964 Chev. – 283 in^3; and (3) 1971 Pont. – 350 in^3.

and deceleration sequences involved in actual driving patterns. The general trend of decreasing CO and HC and increasing NO_x emissions was confirmed for average speeds. HC emissions decrease about half a gram for each 10-mph increase up to 30 mph, with the decrease per 10-mph increase at higher speeds falling to about a quarter or a third of a gram/mile. The shape of the curve for CO is much the same, with decreases of the order of 5 grams/mile for each 10-mph increase in speed up to 30 mph and smaller drops at higher speeds. The NO_x curve is straighter; it shows an increase of 2 grams/mile emitted for each 10-mph increase. The HC and CO results are confirmed by two other studies (248 and 293), but one of these found no relationship between NO_x and speed while the other found some evidence that NO_x emissions increased with higher speeds. In any case, these data and other evidence in References 7 and 239 suggest that the optimum speed from the pollutant emissions point of view lies between 30 and 40 mph.

The effect of the stop, start, and idle cycle on emissions is more clearly shown in Table 2-2, based on a 1967 British report reviewed in Reference 7. CO emissions levels are highest when idling and cruising, lowest when accelerating and decelerating; HC emissions are highest when decelerating and idling, lowest when cruising and accelerating; and NO_x emissions are highest when accelerating, lower when cruising, and lowest when idling or decelerating. Again the CO-HC pattern is the mirror image of the NO_x pattern; from the CO-HC point of view, idling and stops should be minimized, while for NO_x, acceleration should be minimized. Both patterns, however, point to the same overall conclusion: it is during cruising that the lowest concentration of pollutants is emitted from automobiles.

Table 2-2. Concentration of pollutants in exhaust gases during stop-start cycle.

Pollutant	Idling	Accelerating	Cruising	Decelerating
Carbon monoxide, % by volume	7.0	3.0	4.0	3.0
Hydrocarbons, ppm	820	700	500	4,400
Oxides of nitrogen, ppm	30	1,050	650	20

Source: Reference 7, p. 3-1.

Aside from data relating to individual vehicle emissions, there are varying estimates of the effect improvements in traffic flow will actually have on air pollution in urban areas (see Table 2-1). Reference 3 estimates that area-wide traffic flow improvement programs could reduce mobile source emissions by 10 percent in Baltimore and by 2 percent in Boston. Reference 180 estimates that a uniform traffic control program for the Los Angeles area could result in approximately a 3 percent reduction in pollution. Reference 124 states that traffic flow improvements would have a comparatively low effect on air quality.

A possible explanation for these discrepancies is that the base speed of a facility is very important when evaluating the effects of traffic flow improvements on air quality. Speed improvements are much more effective in reducing pollutant emissions when relatively low speeds prevail before the improvements are begun; they become less effective when speeds are already relatively high. The degree of vehicle retrofit is another factor to consider. For pre-1968 vehicles, increasing speed from 10 mph to 15 mph would reduce CO emissions about 29 percent, while increasing it from 25 mph to 30 mph would result in a CO emission reduction of only about 15 percent (133, p. 3-32).

The fact that traffic control improvements encourage long-term VMT growth and induce traffic increases may well outweigh any short-term improvement in pollutant emissions. The three-case congestion example from Reference 133 presented above (see pp. 2-19, 2-20), when used as the basis for calculating changes in emissions over a five-year period following traffic control improvements, results in an absolute decrease in emissions for only the year immediately following implementation, when emissions will be some 17.6 percent lower than before implementation. Emissions would increase at a lower rate for the first two years following the improvements than they would in the base case where no improvements are made, but for all subsequent years, emission levels would be higher than if no traffic flow techniques were implemented at all. In year 5, for example, emissions would be 20-25 percent higher (133, p. D-6). The reason for this is that although speeds following the improvements are always higher than in the no-improvement case, the relative reduction in per-vehicle emission factors associated with the higher speeds becomes rapidly overwhelmed by the additional number of vehicles. The authors of this example conclude that "traffic flow improvements should be viewed only as extremely short-term measures [for reducing air pollution], unless traffic volumes can be reduced or restrained" (133, p. D-8).

Energy Consumption. The effect of traffic control improvements on fuel consumption is very similar to their effect on pollutant emissions: per vehicle fuel consumption decreases as speed increases, within a certain range, and as stops and starts are eliminated, but these savings are cancelled out in the long run by increases in VMT. Steady speeds between 20 and 40 mph are optimum for fuel use efficiency according to Reference 239, while Reference 29 narrows the figure to 25 mph (see Figure 2-3). This suggests that traffic flow improvements, especially those such as signal synchronization, should be designed to obtain speeds close to this value rather than to obtain maximum throughput or speeds.

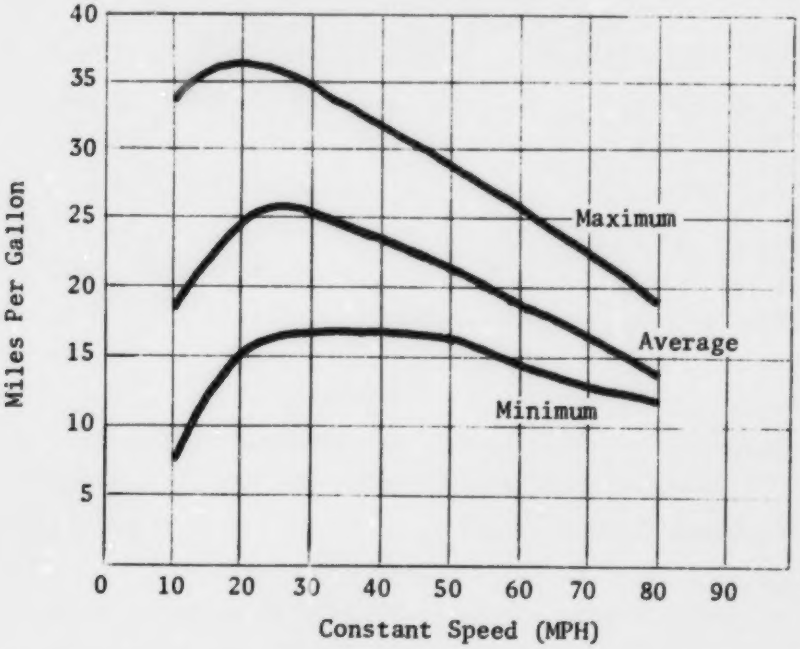
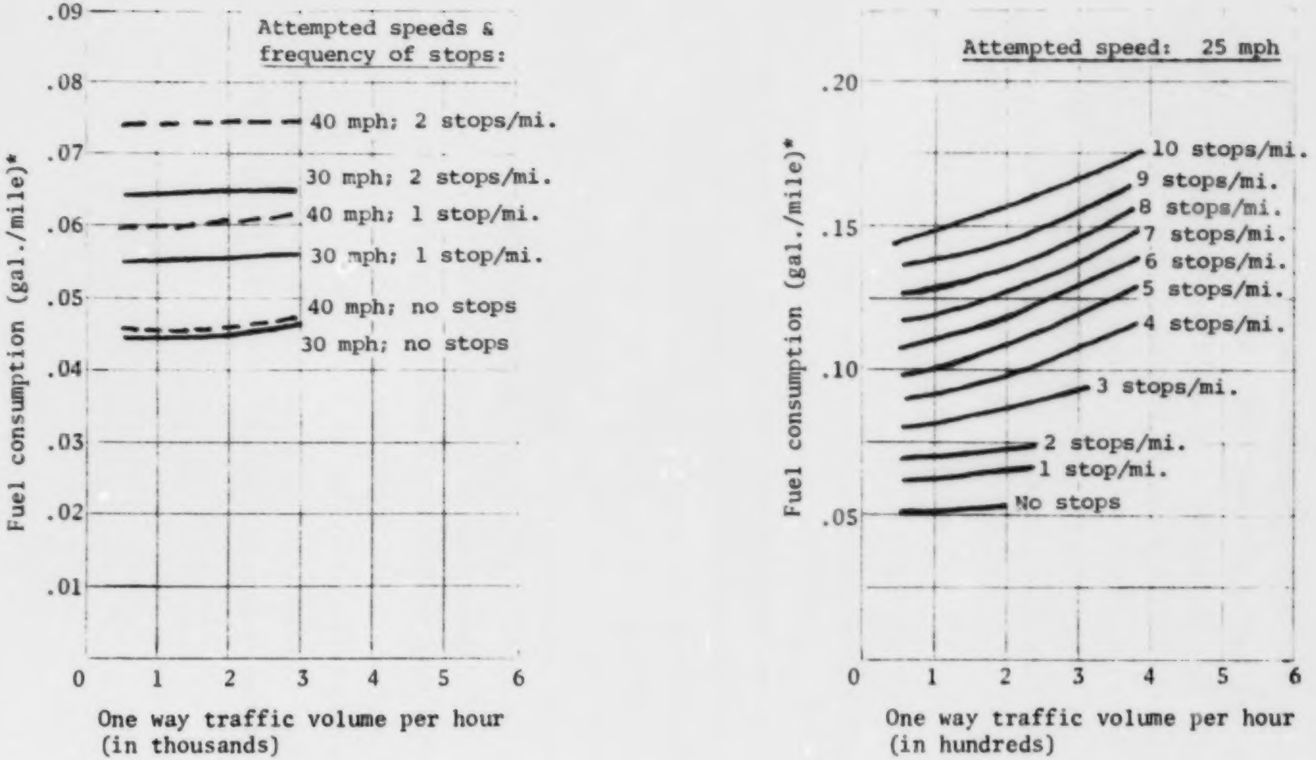


Figure 2-3. Automobile fuel consumption as a function of speed.

Source: Traffic Engineering Handbook, reproduced in Reference 29, p. 2.

Regarding stops and starts, Figure 2-4 shows the effect of the number of stops per mile and of traffic volumes on fuel consumption for two different road configurations, a 6-lane urban arterial and for 4-lane CBD streets. The figure shows that for the urban arterial, fuel requirements in gal./mile increase by two-thirds with the addition of two stops/mile at 40 mph—from .045 to .075 gal./mile. Increasing traffic volumes has little effect on these rates for this type of facility. On CBD streets, the increase in fuel required in going from none to two stops is a little less (45 percent increase), but adding three more stops (5 stops total) doubles the original fuel requirements (.10 gal. vs .05 gal./mile) at the lowest traffic volume shown. Traffic volumes have a marked reinforcing effect on these increases: increasing traffic flow from 100 to 200 vehicles/lane/hour has the same effect as adding one more stop (increases fuel consumption by .01 gal./mile), and this deleterious effect intensifies as traffic volumes increase.

The study from which Figure 2-3 is taken (29) estimates that if a 50 percent reduction in the number of accelerations could be obtained, a 10 percent energy savings for urban driving could be achieved annually (2 billion gallons of gasoline, or 91 million barrels of crude petroleum). However, a 50 percent reduction in accelerations is probably unobtainable; Reference 6 states that improved signal systems in several cities to date have resulted in an average 10-30 percent reduction in stop and go cycles. A uniform traffic control program for the Los Angeles region is estimated to save 85 million gallons of gasoline annually (180, p. 6). Reference 239, which approaches the question of energy consumption only from the standpoint of user costs for fuel, calculates that eliminating one stop along a route would save approximately 0.11 cents in fuel consumption (at 54¢/gal.), while increasing speed from 10 mph to 20 mph would save approximately 0.13 cents/mile (p. 59). However, as with pollutant emissions, these effects, calculated on a per-vehicle basis, may be counterbalanced by increases in the number of vehicles using the facility and in VMT.



a. Six-lane urban arterial

b. Four-lane CBD streets

Figure 2-4. Effect of traffic volume on passenger-car fuel consumption.

*Vertical scales differ by a factor of about 2.

NOTES: Vehicle: 1964 Chevrolet sedan (4400 lbs. G.V.W.), V-8 engine, 283 cu. in. displacement, automatic transmission. Conditions: (a) straight, level 6-lane urban arterial, two traffic signals/mile, no parking, good paved surface, calm wind, 80°-90° F.; Level of Service A - free flowing traffic for 1000 v/h or less; Level of Service E - unstable flow at 3000 v/h or more; (b) straight, level 4-lane CBD street, traffic signals every 500 feet, calm wind, 80°-90° F.; Level of Service A - free flowing traffic at about 50 v/h or less; Level of Service E - unstable flow at about 400 v/h or more.

Source: Reference 51, p. 54.

OVERALL EVALUATION. On the positive side, traffic flow improvements are relatively inexpensive, compared to other strategies such as construction of new roadways or rapid rail lines. They can generally be implemented with very short lead times, and will have immediate benefits. This strategy has been already pretty thoroughly tested and proven effective in substantially improving traffic flows, pollutant emissions, and fuel consumption, in the short term. A federal program has already been established to fund and implement such improvements (TOPICS).

Traffic flow improvements are probably most applicable on CBD streets. Because of their high traffic volumes and low speeds, such facilities probably have the highest potential for emission reductions as a result of traffic flow improvements. Furthermore, according to Reference 7, "Due to the high daytime population densities, reduction in downtown air pollution levels can benefit a relatively large percentage of the population" (p. 3-13).

On the negative side, the most obvious drawback is the tendency for such improvements to have a short life span, so that the final result, in terms of congestion, air pollution, and energy consumption, may be worse than if no improvements had been made. Also, perhaps more than other strategies, it is site specific so that benefits from a specific type of improvement would differ widely from location to location and from city to city, depending on the average speed level before improvements and the need for congestion reduction. Thus, a traffic improvement program costing $7 million in Baltimore has been estimated to reduce emissions by 10 percent, while a similar program costing $9.5 million in Boston is estimated to reduce emissions by only 2 percent (197).

If traffic flow improvements are implemented, it seems clear that for long-range effectiveness they should be accompanied by programs of vehicle restraint (pricing, parking restrictions, vehicle-free zones, etc.; see Section 3), vigorous promotion of transit modes (see Section 1), and perhaps a campaign to reduce the need for travel (see Section 4). Conversely, traffic flow improvements might make vehicle restraint measures more palatable, by insuring that those who were able to use their automobiles would be able to travel on uncongested roadways at design speeds.

Utilize Ramp Metering (2.1.3)

EXPERIENCE. Though ramp metering is usually applied to freeways rather than surface streets, it is, like the traffic flow improvements discussed above, designed to maximize the use of existing facilities rather than to provide significant new capacity. Ramp metering is unique as a form of traffic flow improvement, however, because it involves a slight degree of vehicle restraint and because it can be used to discriminate in favor of transit vehicles as a method of diverting auto traffic to transit. Experience with ramp metering includes projects of varying sizes and complexity in Chicago, Milwaukee, Detroit, Houston, Dallas and Los Angeles. Most of these projects report substantial speed increases on the freeway sections involved, as well as some increase in traffic volume. This experience is summarized in Table 2-3.

The technique of ramp metering when combined with a bus and carpool bypass system could theoretically provide an effective incentive for motorists to switch to buses or carpools. According to Reference 290, however, the use of this technique in Los Angeles has resulted in bus travel time savings but has had little effect in diverting commuters from autos (p. 113). On the other hand, when carpools were provided with a bypass on a metered freeway ramp in Los Angeles, the number of carpools using the ramp increased 120 percent in two weeks, with an estimated 50 percent of the increase believed to be newly-formed carpools.

Ramp metering can be rather costly. Reference 239 cites some 1968 estimates of implementation costs for various types of ramps: auto entrance ramp, $5,000 each; bus entrance ramp, $3,800 each; combination auto and bus entrance ramp, $8,200 each. These figures do not include the costs of office expenses and operation and maintenance of the system, and probably also exclude the price of electronic traffic detection equipment in the freeway lanes. The total cost of a proposed program of expanded ramp metering in the Los Angeles region has been estimated at $60.9 million (180, p. 8), including the cost of widening freeways in some places to eliminate bottlenecks. This project would involve 851 freeway ramps, 35 of which would be provided with bus and carpool bypasses which cost $20,000 apiece.

IMPACTS ON GOALS. When ramp metering was still in the conceptual stage, there was some concern expressed that traffic diverted from the freeways by the metering would contribute to congestion on adjacent surface streets, and

Table 2-3. Documented impact of strategies and actions on offsetting phenomena: Utilize Ramp Metering (2.1.3).

PHENOMENA						COST ESTIMATES	
1.0 Improved Auto Alternatives	2.0 Improved Vehicular Flow	3.0 Reduced Urban Auto Use	4.0 Reduced Urban Travel Demand	5.0 Reduced Vehicular Air Pollutant Emissions	6.0 Reduced Vehicular Petroleum Consumption	Highway, Auto	Rail, Bus & Para-Transit
Reference 239							
Not mentioned.	Traffic as a whole will flow faster and more efficiently, though some individual autos may suffer heavy time penalties (p. 105). In Houston, average speed on metered facility increased from 14 mph to 30 mph (114%), and vehicle-hours decreased 48% (p. 107).	In the Houston case, VMT increased 11% on facility experiencing higher speeds and shorter vehicle-hours (p. 107).	Not mentioned.	Reduction in stop and start traffic movement and in overall vehicle operating time will result in reduced emissions (no quantification to date) (p. 106).	Not mentioned.	1968 implementation cost estimates for one ramp: auto entrance ramp-$5,000; bus entrance ramp-$3,800; combination auto and bus entrance ramp-$8,200; exit ramp-$600; 2-lane detection stations-$600; 4-lane detection stations-$1,800 (p. 104). (Costs for office expenses, operation and maintenance not included.) Overall growth in demand for new facilities would only be checked momentarily by metering projects (p. 108).	Not mentioned.
Reference 180							
Not mentioned.	Proposed ramp metering project for Los Angeles should result in 11 million hours annual savings in motorists' time (p. 8).	Not mentioned.	Not mentioned.	Ramp metering projects to date show 18% CO emission reduction in immediate area. Proposed Los Angeles project predicted to reduce pollution 1% overall (p. 8).	Proposed Los Angeles project estimated to save 24 million gals. of fuel annually (p. 8).	Total cost of proposed Los Angeles program, involving metering of 851 ramps (35 with bus and carpool bypasses): $60.9 million (p. 8).	Not mentioned.

Table 2-3. (continued)

PHENOMENA						COST ESTIMATES	
1.0 Improved Auto Alternatives	2.0 Improved Vehicular Flow	3.0 Reduced Urban Auto Use	4.0 Reduced Urban Travel Demand	5.0 Reduced Vehicular Air Pollutant Emissions	6.0 Reduced Vehicular Petroleum Consumption	Highway, Auto	Rail, Bus & Para-Transit
Reference 290 Buses are given priority at metered ramps by means of a bus bypass lane. To date, resulting bus travel time savings have had little effect in diverting commuters from autos (p. 113).	Negligible diversion of freeway traffic to city streets in Los Angeles project (p. 113).	Ramp metering increased freeway VMT in Los Angeles as a result of motorists attempting to enter freeway upstream from the metered ramp (p. 113). Expanded metering programs will probably result in altered temporal and spatial distribution of traffic, rather than a reduction in travel (p.114).	Not mentioned.	Impact of ramp metering (and removal of freeway bottlenecks) in Los Angeles will be a slight decrease in CO and HC emissions accompanied by an increase in NO_x emissions. Overall will have a minor impact on air quality (p. 111).	Not mentioned.	Not mentioned.	Not mentioned.
Reference 106 No increase in transit ridership observed in Los Angeles project (p. 40).	No increase in surface street congestion obser- in Los Angeles project (p. 40).	Not mentioned.	Not mentioned.	Not mentioned.	Not mentioned.	Cost to meter entire South Coast Air Basin freeway system: $10 million (p. 81).	Not mentioned.
Reference 6 Not mentioned.	Should decrease travel time; no figures (p. 17).	Not mentioned.	Not mentioned.	Should decrease air pollution; no figures (p. 17).	Regional energy reduction from ramp metering, freeway surveillance and driver advisory displays: 0-1% (p. 17).	Not mentioned.	Not mentioned.

therefore that it should be implemented only in locations which had a nearby parallel route with sufficient unused capacity to absorb the diverted traffic. In Los Angeles, however, there has been a negligible diversion of freeway traffic to the city streets, and surveys show that on the average, 30 percent more traffic could be handled on major arteries paralleling freeways during peak traffic periods (290, pp. 3, 114). Thus in Los Angeles diversion of traffic to surface streets has not proven to be a problem. Instead, motorists seem to be shifting their travel patterns in other ways, e.g., entering the freeway upstream from the metered ramp, which has the undesirable effect of increasing freeway VMT.

Ramp metering is generally not considered as having much potential for reducing air pollution and fuel consumption, though there are a few estimates of its impacts on these goals. Reference 7 states that traffic delays at ramps will raise emissions at that point, but that for the freeway as a whole pollution should decrease (p. 3-8). An extensive ramp metering project in Los Angeles is predicted to show an 18 percent CO emission reduction in the immediate area of the ramp and an overall pollution reduction of 1 percent (180, p. 8).

Fuel consumption would probably be affected very little, since the gains from increased freeways speeds would be offset at least to some degree by losses due to time spent idling at the ramp. The proposed Los Angeles project is estimated to save 24 million gallons of fuel annually (180, p. 8).

OVERALL EVALUATION. Though ramp metering has the drawback of being aimed primarily at congestion, with not many foreseeable beneficial impacts on air quality and energy consumption, it has proven effective in improving freeway flow; about a 35 percent speed increase on the freeway sections involved has been reported by several projects. Ramp metering is superior to the other traffic flow improvements which also demonstrate substantial speed increases because it does not suffer from the disadvantage of possibly being self-defeating in the long run. By definition, a ramp metering system precludes the possibility of a facility returning to earlier congestion levels, since the metering system is set to operate at the optimum level of access. Thus, even though there might be an increase in VMT carried, this would be offset by gains due to lower emission and fuel consumption rates, providing that speeds are kept in the 30 to 40 mph range. The problem with traffic flow improvements on surface streets, on the other hand, is that speed tends to decline as the facility once again reaches capacity, so that not only VMT but also emission and fuel consumption rates increase because of the return to congested traffic conditions.

Ramp metering also has the advantage that it could be used to encourage the diversion of auto users to transit by adding bus and carpool bypasses. The greater ease of these vehicles' entry onto the freeway would encourage diversion either to transit or carpooling, or to surface streets. Indications to date are that congestion on surface streets would not increase as a result, but since no extensive regionwide ramp metering system has yet been implemented, this requires verification.

On the negative side, ramp metering can be rather expensive, certainly more so than most of the other traffic flow improvements. It has also been argued that if road pricing is proven to be technically and politically feasible (see Section 3, 3.2.1), it would be a much more efficient, sensitive, and flexible means of obtaining the same results as ramp metering, i.e., optimizing freeway traffic flows (349). Metering does not actually eliminate queuing, but merely transfers queues to locations where they, hopefully, have less serious effects on the traffic flow. However, road pricing discriminates against those who cannot afford the toll, while metering discriminates against those who cannot afford the time to wait to enter the freeway. Thus in this sense metering could be more socially equitable than road pricing.

Possibly the most important characteristic of ramp metering is that it effectively enforces optimum use of the facility it controls without tempting new travelers or facilitating new trips. To the extent that optimum use of each mode and each facility is a goal of an ideal urban transportation system, ramp metering is a necessary policy tool.

Dedicate Lanes for Transit and Carpool Use (2.1.4)

EXPERIENCE. The dedication of freeway lanes for use by transit or carpool vehicles is a relatively new technique not yet widely in use. In principle, assigning exclusive rights-of-way to buses should increase overall passenger throughput capacity on the roadway and reduce bus travel times so that motorists are induced to switch to bus, possibly thereby lightening traffic on parallel auto lanes. So far, applications have been limited to a few large (2 million and over) cities where specially constructed rights-of-way or contraflow lanes have been dedicated to bus use (busways). Only on the Shirley Highway busway are carpools allowed to use the lanes, though it would theoretically be feasible for any busway to be used by carpools or other multi-occupant vehicles such as para-transit. To date, however, experience has been mostly with bus only lanes.

Operations and Costs. Because few busways are in operation and each one has been tailored to local conditions, needs, and finances, it is sometimes difficult to generalize about busway operating and service characteristics. Table 2-4 displays information for 6 major busways in Washington, D.C., Los Angeles, New York, Boston, and Seattle, showing operational, market, and cost characteristics, travel time savings, and changes in auto speed. Three of the busways are on contraflow lanes (Lincoln Tunnel approach, Long Island Expressway, Boston Southeast Freeway), two are on separate rights-of-way (Shirley Highway and San Bernardino Expressway), and one uses an exclusive ramp to enter mixed traffic (Seattle Blue Streak). Although the last-mentioned is essentially an express bus service with its own freeway entry ramp rather than a busway service on exclusive right-of-way, it delivers the same quality of service as the others at a lower demand density, and therefore it can be understood as a kind of preliminary stage to implementing a busway. If demand for the bus service continues to build to the point where a separate bus lane is justified, such a lane could be created. Thus two service characteristics of busway operations are important: they provide express service on freeways (fewer stops), and they are segregated from auto traffic for at least part of their journey (higher speeds).

The Lincoln Tunnel and Shirley Highway facilities carry the greatest traffic volumes, 34,000 and 11,300 per A.M. peak period respectively. (All figures are for one lane.) The Long Island Expressway lane carries 7,500, the San Bernardino busway about 4-5,000 (estimate*), and the Boston and Seattle

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*Daily ridership was 11,000 on two lanes as of November 1974 ("Freeway Bus Station Dedicated," Los Angeles Times, 4 November 1974). While the busway has two lanes carrying buses in opposite directions, in Los Angeles the traffic flow is high during peak hours in both directions; therefore somewhat less than half the daily flow is considered to be a rough estimate of traffic carried during the A.M. peak period.

Table 2-4. Operating, market, and cost characteristics of 6 busways on freeways.

	SPECIALLY CONSTRUCTED SEPARATE ROW		CONTRAFLOW BUS LANES ON EXISTING FREEWAYS			EXCLUSIVE BUS FREEWAY RAMP
	(1) Shirley Highway, Northern Virginia to Washington, D.C.	(2) San Bernardino Expressway, El Monte to Los Angeles CBD	(3) Approach to Lincoln Tunnel, New Jersey to New York City	(4) Long Island Expressway, New York City	(5) Southeast Freeway, Boston, Massachusetts	(6) Seattle "Blue Streak" Project, suburbs to Seattle CBD
OPERATIONS						
No. of lanes	2 reversible lanes	2 lanes; 2-way operation	1 contraflow lane	1 contraflow lane	1 contraflow lane	2 reversible lanes (shared with mixed traffic)
Hours of operation	Open all day; major use during peak periods	Open all day.	am peak period only (7:30-9:30)	am peak period only (7:15-10:00)	am peak only (7:00 -9:30)	7:00 am - 7:00 pm (express bus)
Special Features	Limited priority measures for bus distribution in downtown Washington, D.C.; carpools allowed on busway since 12/73; fringe parking lots planned.	Uses contraflow bus lane in L.A. CBD. Fringe parking for 700 cars, 700 more spaces planned. Carpools will be experimentally admitted later.	Lane terminates at N.Y. Port Authority Bus Terminal which interfaces with other transportation.	N/A	Only in operation from April to October for safety reasons (short daylight hours in winter).	Exclusive use of reversible CBD freeway ramp; special express bus service from 525 space park-n-ride lot; now planning additional 1000-space lot.
Miles of Facility	9. (4.5 are a 1-lane "temporary busway" still under construction)	11	2.5	2.2	8.4	8 (from park-n-ride lot)
Vehicles:						
Per am peak period	275	100 (projected per peak hour)	Average: 818 High: 1096 (597 for 8 - 9 am)	180	82	N/A
Per day	N/A	N/A	am only	am only	am only	81
Average speed (mph)	40-60	40	45	30-40	45	N/A
MARKET						
Passengers:						
Per am peak period	11,300	4,000 per hour (projected)	Average: 34,350 High: 47,800	7,500	3,160	3,083 (count on exclusive bus ramp)
Per day	24,300 (1973)	17,000 (projected); 5,000 (when 60% complete); 6,900 (3/74)	6% increase in daily peak period bus riders	am operation only	am operation only	10,000 (up from 7,500 at beginning of project)
Per vehicle	43	N/A	42.2	N/A	N/A	N/A
Market Share	36% (Oct.71); buses were carrying as many pass. as autos on Shirley Highway.	N/A	Bus lane carries 10 times more pass. than any of the regular tunnel-bound auto lanes.	N/A	N/A	N/A

N/A = not available

Table 2-4. (continued)

	SPECIALLY CONSTRUCTED SEPARATE ROW		CONTRAFLOW BUS LANES ON EXISTING FREEWAYS			EXCLUSIVE BUS FREEWAY RAMP
	(1) Shirley Highway, Northern Virginia to Washington, D.C.	(2) San Bernardino Expressway, El Monte to Los Angeles CBD	(3) Approach to Lincoln Tunnel, New Jersey to New York City	(4) Long Island Expressway, New York City	(5) Southeast Freeway, Boston, Massachusetts	(6) Seattle "Blue Streak" Project, suburbs to Seattle CBD
PASSENGERS DIVERTED FROM OTHER MODES						
Auto	18% (2,000 trips/day)	N/A	4%	N/A	N/A	22% (50% of patrons using the park-ride lot were diverted from autos.)
Carpools	13%	N/A		N/A	N/A	N/A
Other bus	20%	N/A	9% (81% rode same bus as before)	N/A	N/A	N/A
New trips	49%	N/A	3%	N/A	N/A	10%
SAVINGS						
Travel time savings:						
Over Autos						
Minutes	am - 25; pm - 20	18-20 (projected)	N/A	5-15	7½	N/A
Percent	am - 58%*; pm-54%	50%	N/A	22-75%	42%	N/A
Over former bus						
Minutes	N/A	N/A	7.5-10	N/A	14	5-11
Percent	N/A	N/A	N/A	N/A	58%	11-23%
Increase in auto mph since facility opened	N/A	N/A	Speeds on several approaches to the tunnel increased: from 4 to 40 mph in one case; from 10-30 mph in two other cases.	N/A	Travel time for autos dropped from 22 to 17.5 minutes.	N/A
COSTS						
Implementation	$820,000/mile for 2-lane portion; $620,000/mile for 1-lane temp.busway.	$46,290,000 total construction & ROW. (Approx. $10,000,000 add'l for vehicles, project management, etc.)	Access road to bus lane: $134,000. Implementation of lane: $342,317. Design traffic control plan: $60,325.	$44,100	$39,706	N/A
Operating	Normal roadway maintenance costs.	Normal highway maintenance costs.	$500/day for crew to change lane directions each morning. ($176,000/yr. for 1971).	$500/day.	$542/day.	N/A

*Shirley Highway auto driving times are constrained by extensive on-going highway construction.

Sources: (1) 86, 240, 353; (2) 35, 106, 220, 240; (3) 105, 240; (4) 240; (5) 240; (6) 2, 240, 327.

busways about 3,000 passengers per A.M. peak period. Due to the differences in facility length, the ranking for passenger-miles carried is somewhat different. The Shirley busway carries the greatest number of passenger-miles per A.M. peak period (101,000), with the Lincoln Tunnel contraflow lane a close second (85,000). The San Bernardino busway carries only roughly half as many passenger-miles per A.M. peak period as the top two busways (44-55,000), but roughly two to three times as many as the other three (Boston, 26,500; Seattle, 24,700; Long Island Expressway, 16,500).

Information on diversion from auto modes is scanty and inconsistent. Roughly 20 percent of Shirley and Seattle busway passengers were diverted from auto, but on the Shirley facility as many were diverted from other bus routes and 13 percent from carpools; 49 percent were new trips, compared to 10 percent for Seattle's Blue Streak. Evidence of the impact of introducing busways on highway capacity and auto traffic is equally difficult to evaluate, as discussed below under "Impacts on Goals" (p. 2-40 ff.). Each case seems to be different, and the results vary with the age of the service.

Capital costs also appear to differ considerably due to variations in right-of-way acquisition and need for special structures, from $600,000 to $2 million per lane mile for constructing special bus rights-of-way, down to $44,000 to $540,000 for implementing a single contraflow lane about 2 miles long (see Table 2-4). These variations are also due to inflation and to variation in the cost of roadbuilding from city to city, since for a specially constructed busway lane, construction and maintenance costs are usually considered to be roughly the same as for a regular freeway lane.

Apart from this diversity in busway length, configuration, passengers carried, impact on congestion, and capital costs, there seems to be better agreement concerning travel time savings and operating costs. Travel time savings on busways compared to auto commuting are significant: on the Shirley Busway, the savings range up to 25 minutes. In all cases reviewed in Table 2-4, savings over auto time are around 40 to 50 percent. Reference 240 considers this to represent "a major commuter improvement" (240, p. 122).

Regarding operating costs, as the table shows, roadway maintenance costs for new facilities are the same as for a conventional roadway, with roughly $500 per day additional required for lane marking on the facilities converted from auto use. As far as vehicle operating costs are concerned, buses operating on busways usually have better revenue-cost ratios than conventional transit buses. Because they operate at higher speeds, with less stop-and-go driving, their per-mile operating costs are lower, as shown by data collected in Seattle and the District of Columbia, displayed in Table 2-5, and they experience less wear and tear, especially on brakes and transmission systems. Some companies whose buses use exclusive busways also report less paid driver overtime. In general, both vehicle and driver productivities are improved. Even so, these bus companies still require some subsidy, though it is reported that buses using the Shirley Busway generated a substantial surplus of revenues over expenses for the peak-period routes, which was large enough in October 1971 to cover losses for off-peak service (86, p. 35).

Table 2-5. Comparison of operating costs for Seattle Blue Streak express bus service and regular bus operations.

	Average Cost per Vehicle Mile		
	Peak Period	Base Period	Daily
Blue Streak Routes			
Express bus service	$1.39	$0.64	$1.00
Local service	1.49	0.72	1.06
Control Routes (Seattle)	1.41	0.71	1.04
Shirley Busway Buses	0.80-1.27	n.a.	0.43-0.50

Source: Reference 62, pp. 3-4.

Busway-related Improvements. INTERPLAN's review of busway experience revealed an important point regarding busway planning and implementation. It is generally agreed that construction or reservation of a busway must be accompanied by other auxiliary actions in order for the project to successfully attract a significant number of motorists. Busway planning usually involves a review of the entire routing and scheduling, and rerouting and rescheduling of some lines, while implementation requires construction of adequate fringe parking lots and additional measures to speed bus flow on the non-busway portions of the route.

Providing fringe parking facilities (park-and-ride) seems to be the most effective measure for increasing the attractiveness of busway service to potential patrons. Seattle's Blue Streak system reported that of patrons surveyed at the park-and-ride lot, 50 percent were former auto users, compared to 22 percent for all bus riders. The greatest increase in Blue Streak ridership occurred on routes that included park-and-ride service. Parkers in the 500-car Seattle lot now overflow onto neighboring streets, and the city is seeking funds for construction of a 1,000-car lot. More parking facilities are also needed for Shirley Busway. Designers of the San Bernardino facility have heeded the experience of these earlier busways and built a 700-car lot with the busway, with plans to add another 700 spaces later.

Lack of capacity on CBD streets is another significant limiting factor in the success of busways. Building a busway or reserving a bus lane to increase the number of buses entering the downtown area when these streets cannot absorb any more vehicles would mean that time saved traveling on the busways would be offset by time lost downtown due to increased congestion. Bus traffic signal pre-emption or priority, exclusive bus lanes on arterial streets, and off-street terminal facilities in the CBD represent three potential solutions to this problem. Under mixed traffic conditions, the impact of bus traffic signal preference on bus travel time is expected to be minor, but if implemented in conjunction with an exclusive bus lane, savings of up to 10 percent of total busway trip time may be obtainable when other traffic conditions are favorable (240, p. 7). Reserving lanes for buses in the CBD might be a more effective means of accomplishing the same end. While exclusive bus use of downtown arterials, usually utilizing contraflow lanes on one-way streets, has not been as dramatically successful to date as bus lanes on freeways (239, p. 7), the combination of these two approaches would assure that the time saved by express buses on freeways would not be lost in city traffic delays. Both the Shirley Highway and San Bernardino Busways' buses operate on bus priority lanes in some portions of the CBD.

In addition, off-street bus terminal space in the CBD may be required if congestion is serious and bus volume high. For example, even though Shirley Busway is operating at far below capacity on the line-haul portion, the capacity of the downtown curbside terminals has almost been reached. Thus, the bus fleet cannot be substantially increased without adding new terminals and street routings to extend the reserved CBD bus lane network (353, p. 22). In New York City, the Department of Traffic is reluctant to allow additional buses to use the contraflow lane on the Long Island Expressway because it feels there is inadequate terminal loading and unloading space in Manhattan to accommodate more buses (240, p. 32). A high-quality busway would require exclusive transit areas in the city center, such as the Lincoln Tunnel-Port Authority Terminal in New York City (353, p. 27). All bus routes utilizing the Lincoln Tunnel approach busway terminate in the Port Authority Terminal, located on the far side of the tunnel, where passengers may transfer to other modes such as subway and taxi.

Applicability. In order for busways to be able to attract passengers from autos, buses using the facility must demonstrate appreciable time savings over auto travel, which they will do only if they can circumvent congested queues. This suggests that busways would be superfluous in small cities or urban areas which experience only slight congestion. It has also been suggested that busways are best suited to radial corridors, usually with one end in the CBD (239).

Several rules of thumb have been developed to guide in the decision to set aside a lane for bus use. There is no advantage in reserving one lane in a 3-lane freeway corridor (one direction) for buses and carpools because the other two lanes would be so congested that the buses and carpools could not cross over to reach the exclusive lane. For freeways with four or more lanes in one direction, the feasibility of dedicating an exclusive lane to buses and carpools would depend on total traffic demand, the potential number of buses and carpool vehicles, and traffic control enforcement problems (106, p. 39). Another general rule is that if the number of passengers carried in buses on a busway is expected to equal or exceed the number of passengers carried in automobiles by a paralleling lane of traffic, then the reservation of one lane for exclusive bus use is amply justified (240, p. 6).

This last rule could easily be used to defeat proposed busways if too great a reliance is placed on current transit patronage as an indicator of expected busway passenger volume. As with other transit and para-transit measures, some willingness is required on the part of local officials to take the initiative in offering auto alternatives. To quote the R. H. Pratt Associates study of U.S. busway applications, "This study would contend as one of its *major findings* that unless low capital transit alternatives which genuinely improve commuting through time savings are made available, communities will have no choice except continued heavy investment in capital facilities whether they be highways or rail. A single lane established as a bus lane does provide a genuine alternative to heavy investment in other capital facilities" [italics added] (240, p. 122).

Table 2-6 shows U.S. cities' own evaluation of their need for busways and busway-related facilities. These estimates were made in conjunction with the Highway Needs Report on the basis of a survey of 70 percent of all urban areas containing more than 500,000 people, which included nearly 90 percent of the urban population. The total 20-year busway needs estimate is nearly $6 billion, with roughly equal amounts of funds required by cities between 50,000 and 2 million population and those with over 2 million. As suggested in the discussion above, the larger the city, the greater the estimated need for busways. Cities over 4 million would spend about $19 million apiece each year over the 20-year period if the estimated amount were divided equally among them, while cities in the 1.5 to 2 million range would spend about half that much; and cities below 500,000 population estimated very little need for busways (less than $1 million a year for all cities in this group).

IMPACTS ON GOALS. The impact of busways on congestion, air pollution and energy use depends on the extent to which they permit the freeway to carry the same number or more passengers in less time (at higher speeds and lower traffic volumes) by attracting motorists on that freeway, particularly commuters, to ride the bus. The impact on air pollution and energy use also depends on the energy requirements and pollutant emissions of the bus vehicles compared to those of the autos for which they substitute.

Congestion. Although existing busways are carrying more passengers/lane/hour than auto lanes, they could carry even higher traffic volumes. To date, bus transit has not attracted riders in the volumes necessary to fully capitalize on potential bus capacity (240, p. 2). Maximum freeway capacity when used by autos carrying 1.5 passengers per vehicle is 3,000 passengers per lane per hour (134, p. 20). This volume is not attained, however, until traffic has reached unstable flow conditions (30-35 mph); passenger/lane/hour volumes when flow is free (60 mph) or stable (50 mph) are much lower (1,050-1,800) (122, p. 253). To attain the maximum capacity of an auto freeway lane, 60 buses per hour would

Table 2-6. Estimated busway needs in U.S. cities, 1970-1990.

Urban Area Population (000)	Number of Areas	Estimated Needs (in millions of dollars)					
		Busway	Fringe Parking	Terminals	Other	Total	Total Per City
50-500	218	$ 2	$ 4	$ 2	$ 9	$ 17	*
500-750	14	355	163	10	25	553	39
750-1,000	5	232	104	10	18	364	73
1,000-1,500	8	302	187	24	56	568	71
1,500-2,000	6	690	291	7	52	1,042	174
2,000-4,000	4	543	301	7	49	900	225
4,000 or more	6	1,309	688	201	130	2,328	388
Total	261	$3,435	$1,736	$261	$340	$5,772	22

*Less than $100,000.
Totals may not add due to rounding.

Source: Reference 312, p. 62.

be required carrying 50 passengers each (this 100 percent occupancy rate could be attained if standees during peak-hour operations balanced out off-peak empty seats). Most busway services have a much higher rate of passenger throughput. The busways described in Table 2-4 carry from 90 vehicles/hour to 100-150/hour, with one value of 400/hour (Lincoln Tunnel approach). The Seattle Blue Streak, a lower volume operation, has a vehicle flow of only 35-40 buses/hour. Occupancies for these operations average about 40-42 passengers/vehicle (80 percent of capacity), so passenger/lane/hour volumes are in the 4,000-5,000 range, or 30 to 60 percent higher than maximum auto freeway capacity, with the Lincoln Tunnel approach showing a freakish 15,000/hour flow.

These capacities are all the more impressive in light of the fact that when auto traffic is slowed by congestion to forced flow conditions,* as would be expected on routes suggested for bus lanes, auto passenger volume drops below capacity and can vary from 0 to capacity, depending on vehicle entry and "jam" conditions (122, p. 253). Where a sudden demand surge occurs, as might be expected during commuter rushes, auto freeway service speed can drop from 40 mph to below 30 mph almost without transition, so that freeway volumes never reach the capacity flow levels typical at 30-35 mph speeds before congestion leads to forced flow conditions (122, p. 251). It is easy to see how, in the case of the Lincoln Tunnel approach, implementing a contraflow bus lane improved overall vehicular traffic flow on the existing tunnel-bound lanes more than adding another lane of mixed (auto and bus) traffic would have (240, p. 27).

Although a busway can clearly carry more passengers than an auto freeway lane, so far it has been difficult to determine whether in general enough commuters will switch to bus to measurably reduce auto traffic on freeways. Since creating a bus lane from scratch or by borrowing a lane in the reverse flow direction does not decrease existing auto lane capacity, it does not directly change existing auto flow, and thus does not in itself create any pressure on drivers to seek means of avoiding driving. The bus facility must attract auto riders by offering better service than auto freeway driving. It is unquestionable that commuters are being attracted to busways, as indicated by ridership increases and by the fact that, like dial-a-ride patrons, patrons of busway services tend to have higher incomes and car ownership rates than conventional transit riders. This indicates that medium-high income, automobile-owning suburbanites can be attracted to transit, if provided with the type of reliable, convenient, and fast service which express buses on busways can deliver, as long as (1) travel time savings remain high, and (2) adequate park-and-ride capacity is provided. For example, auto person trips on Shirley Highway dropped from 12,000 per day to 7,500 per day after the busway was implemented. Some part of this decrease was due to extensive highway reconstruction underway at the time, but at least some of these lost trips were transferred to bus rather than to driving an alternative route, since 24 percent of former auto drivers who switched to the bus said they did so because of "traffic inconveniences". But 35 percent of those people who had a car available but were riding the bus were doing so because the bus was faster (86).

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*See Table 8, Volume 4 (142, p. 25) and accompanying text for a definition and discussion of freeway traffic flow conditions.

In Los Angeles, while drivers did begin switching to buses, removing their cars from freeway lanes, other cars which had been using parallel surface streets moved onto the freeway as space became available. Thus, while bus patronage continues to increase on the busway, traffic is still heavy on the freeway and parallel surface streets (220, p. 11). Most bus companies whose buses use the exclusive lane for the Lincoln Tunnel approach have reported "small increased patronage"; unfortunately, more conclusive data on ridership and revenue improvements is not available (240, p. 27). Rider surveys do indicate that only 4 percent of bus riders were former car drivers or carpool members. However, this statistic mainly reflects the fact that in this case, buses already carried over 80 percent of the persons passing through the tunnel during the peak period prior to the opening of the busway; thus there was little room for further modal diversion. The Seattle Blue Streak project has been one of the most successful in terms of attracting new riders (2, Vol. 1, p. 21). Introduction of the new express service, designed to supplement service on existing routes, increased patronage more than one-third over prior ridership levels, from about 7,500 to over 10,000 passengers per day, as measured in passenger counts on buses entering and leaving the CBD. The greatest increases occurred on routes that made use of a park-and-ride lot.

AIR QUALITY AND ENERGY CONSUMPTION. Decrease in pollutant emissions and energy consumption due to busways depends not only on the magnitude of the shift from car to bus but also on the energy requirements and emission rates of the buses compared to the private autos which they would replace. INTERPLAN calculated comparative energy consumption and emission rates for bus and auto in Volume 2 of this study on the basis of data for bus operations in mixed traffic (see Table 3, 144a, p. 16). However, the auto emission rates used in that table are the 1977 EPA standards; for current calculations, some earlier year's standards would be more reasonable. Also, the bus emission rate used assumes that half the bus fleet will be LPG powered, which may be reasonable for 1990 but not for the current fleet. For these reasons, another table has been prepared for this discussion, using estimates of current rates.

Table 2-7 shows the comparison on a per vehicle basis between auto and bus fuel requirements and vehicle emissions, assuming current fuel consumption and emission rates. The auto emission rates used are those required by EPA for 1973 vehicles; this probably favors the auto case, since average emissions of the vehicle population are probably higher than the 1973 standards. The estimates for the express bus operations are computed by assuming that fuel consumption rates are a 50:50 weighted average of conventional and intercity bus rates. The emission rates for conventional bus are adjusted to give express bus emissions using speed-related factors derived from Figure 2-2 (p. 2-21) assuming that express buses average 40 mph (see Table 2-4) and conventional buses average about 20 mph (INTERPLAN estimate). The data on auto emissions as a function of speed represented in Figure 2-2, from which the adjustment factors are derived, are not authoritative; some researchers have found less of an increase or no increase in NO_x with increases in speed. Furthermore, these functions may also be different for diesel bus engines; however, INTERPLAN has no better data at present.*

From the energy consumption point of view, the table shows that at a car occupancy of 1.5, a 50-passenger bus would be contributing a net gain in energy equal to the auto energy consumption rate (.074 gal./mile) for every 1.5 pas-

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*Emission and fuel consumption rates for buses on busways have been calculated in another study (132, pp. 51-54), but INTERPLAN feels that the assumptions made for these calculations are inaccurate. Emissions of buses on busways are assumed in Reference 132 to be lower than those of buses in conventional operations by the ratio of the respective fuel consumption rates, although it is known that emissions are as much a function of vehicle speed as of fuel consumed and that NO_x emissions increase rather than decrease with higher speeds. Also, fuel consumption for buses on busways is assumed to be the same as for intercity buses. INTERPLAN feels this overstates fuel economy for buses on busways, because intercity buses travel at speeds of 55 or 60 mph, compared to the 40 mph typical of buses on busways.

Table 2-7. Estimated fuel consumption and pollutant emission rates and breakeven occupancies for urban auto and bus operations.

	Rates per Vehicle			Breakeven Occupancies[1] (passenger-mi./veh.-mi.)		
	Auto	Conventional Bus	Express Bus	Auto	Conventional Bus	Express Bus
	(gal./mi.)					
Energy Consumption	.074[2]	.226[3]	.192[4]	1.0	3.0	2.6
				1.5	4.6	3.9
				2.0	6.1	5.2
				2.5	7.6	6.5
	(grams/mi.)					
Vehicle Emissions:						
CO	3.4[5]	23.2[6]	17.4[4]	1.0	6.8	5.1
				1.5	10.2	7.7
				2.0	13.6	10.2
				2.5	17.1	12.8
NO_x	39.0[5]	28.1[6]	114.3[4]	1.0	1.0	2.9
				1.5	1.5	4.4
				2.0	2.0	5.9
				2.5	2.4	7.3
HC	3.0[5]	3.8[6]	2.8[4]	1.0	1.3	0.9
				1.5	1.9	1.4
				2.0	2.5	1.9
				2.5	3.2	2.3

[1] "Breakeven" occupancies are occupancies at which moving a given number of passengers one mile will create the same amount of pollutant emissions or require the same amount of fuel whether the passengers are moved by one bus or several autos. These occupancies are calculated by dividing the bus emission or fuel rate by the auto rate per passenger. Different bus occupancies are calculated by assuming values to the auto rate per passenger (auto occupancy).

[2] DOT estimate; see Volume 2, Table B-4 (144a, p. B-16).

[3] IDA estimate; see Volume 2, Table B-4 (144a, p. B-16).

[4] INTERPLAN estimate; energy consumption figure is a 50:50 weighted average of conventional bus fuel requirements, shown in the table, and of intercity bus fuel requirements, .157 gal./mi. (132, p. 53).

[5] 1973 light-duty motor vehicle emission standards issued by EPA; See Volume 4, Table 15 (142, p. 41).

[6] See Volume 2, Table B-5 (144a, p. B-17).

sengers (one carload) after the first 5 passengers. Five passengers is therefore the "bus breakeven occupancy" when auto occupancy is 1.5. At higher car occupancy rates, which are not likely to be attained even during peak periods (see 3.1.1, Encourage Carpooling), the breakeven bus occupancy is a little higher (5-8 passengers), but it is still considerably below the 1973 average occupancy of about 19. There is little difference between the breakeven points of conventional and express buses; in effect, the roughly 6 percent advantage in fuel economy which the express bus enjoys represents a net gain in itself but does not have much effect on the comparative per-passenger efficiency of buses vis-a-vis autos.

From the pollutant emissions point of view, the breakeven occupancies for conventional buses are much lower for NO_x and HC emissions (1.5 and 1.9 passengers respectively) than for energy consumption, reflecting the fact that diesel bus emissions do not differ significantly from those of 1973 cars. The breakeven occupancy is much higher for CO emissions (10.2 passengers). The differences between conventional and express bus breakeven occupancies are greater than in the case of fuel economy. The express bus breakeven occupancy is lower for CO (7.7 passengers vs 10.2 for conventional bus) and HC (1.4 vs 1.9), but higher for NO_x (4.4 vs 1.5).

From this exercise one may conclude that even at very low occupancies, buses on freeways are more energy efficient and less polluting than autos and buses in conventional operations. There is no question that if auto commuters can be shifted from cars to buses on busways, even if the numbers are not sufficient to reduce congestion, fewer pollutants will be emitted and less petroleum fuel will be required. This will be true even if commuters now using conventional buses switch to express buses on busways or even in mixed traffic (as in Seattle Blue Streak), as long as they can travel at busway speeds (40 mph).

On the other hand, the magnitude of the overall benefits may not be very great. Table 2-8, which summarizes the available estimates on overall impact, shows energy and air quality gains in the 2 to 3 percent range. Nevertheless, EPA is strongly backing busway implementation as a VMT control measure, and in fact ranks it as a number one priority measure along with vehicle inspection and maintenance programs (336, Appendix D).

Table 2-8. Documented impact of strategies and actions on offsetting phenomena: Dedicate Lanes for Transit and Carpool Use (2.1.4).

PHENOMENA						COST ESTIMATES	
1.0 Improved Auto Alternatives	**2.0 Improved Vehicular Flow**	**3.0 Reduced Urban Auto Use**	**4.0 Reduced Urban Travel Demand**	**5.0 Reduced Vehicular Air Pollutant Emissions**	**6.0 Reduced Vehicular Petroleum Consumption**	**Highway, Auto**	**Rail, Bus & Para-Transit**
References 239 and 240 Bus ridership increases: see Table 2-4 for figures on individual systems.	Substantial travel time savings for bus passengers: see Table 2-4 for figures on time savings over auto and former bus times and increases in auto speed.	See Table 2-4 for figures on auto trips diverted.	Not mentioned.	New Shirley Highway buses are being equipped with environmental improvement kits to reduce emissions (239, p. 35).	Not mentioned.	Capital cost of constructing a separate freeway busway is about the same as for a similar automobile roadway (239,p.34). There is evidence to indicate that busways serve as direct substitutes for more traditional capital intensive auto or rail facilities (240, p. 4).	For contraflow bus operations on the N.Y. Lincoln Tunnel approach, 3/4 of the bus companies using the facility reported decreases in paid driver overtime (239, p. 26). Productivity of bus drivers and vehicles will probably improve with busway operations (239, p.34). Reduction in vehicle wear and tear: more miles between brake, clutch and engine overhauls (240, p. 5).
Reference 6 No figures.	Decrease in congestion, no figures (p. 17). Can create additional congestion if traffic volume is not reduced by availability of the bus service (p. A-5). For Pittsburgh, estimated travel time ratio reduction from 1.7 to 1.1 (p. A-3).	For Pittsburgh, estimated VMT reduction of 2% in CBD (p. A-3).	Not mentioned.	Decrease in pollution, no figures (p. 17).	Bus lanes on city streets: up to 2% regional energy reduction. Reserved bus freeway lanes and ramps: 1-3% regional energy reduction (p. 17).	Not mentioned.	Not mentioned.

Table 2-8. (continued)

PHENOMENA						COST ESTIMATES	
1.0 Improved Auto Alternatives	2.0 Improved Vehicular Flow	3.0 Reduced Urban Auto Use	4.0 Reduced Urban Travel Demand	5.0 Reduced Vehicular Air Pollutant Emissions	6.0 Reduced Vehicular Petroleum Consumption	Highway, Auto	Rail, Bus & Para-Transit
Reference 312							
Estimated 300,000 additional bus commuters could be attracted (p. 66).	No figures.	Estimated reduction of 83,000,000 auto VMT per day (p. D-11).	Not mentioned.	Estimated percentage reductions: CO - 2.16%; HC - 2.23%; NO_x - 2.26% (p. D-16).	Not mentioned.	If $5.2 billion were spent by 1990 on busways, fringe parking facilities and bus operation improvements in 29 surveyed cities (over 500,000 pop.), it would eliminate the need for 673 miles of new highways, estimated to cost $6.5 billion. Net savings thus would be $1.3 billion (p. 64). Annual value of time savings for existing transit passengers and carpool members shifting to busways: $397,000,000 (p. 66). Annual savings in auto ownership and operating costs for auto users diverted to busways: $855,000,000. Parking cost savings: $42,500,000 (p.67).	National needs, 1972-1990: busways - $3,434.6 million; fringe parking facilities - $1,736.3 million; terminals and other improvements - $601.9 million.

OVERALL EVALUATION. In general, the gains from implementing busways, though not spectacular, are felt to at least balance out the costs even when considered as an isolated activity. First of all, the busways now in operation have already proven their effectiveness in reducing travel time, attracting riders, and improving traffic flow. Secondly, setting up a busway is a low-cost activity. Implementation costs are low and operating costs are lower than for conventional bus operations. Thirdly, a busway can be implemented quickly and its impacts evaluated within a relatively short period of time compared to other recommended actions. Fourthly, even a short stretch of exclusive bus lane can have a dramatic effect on bus travel times, as in the case of the two facilities leading into New York (see Table 2-4), if it permits buses to bypass a chronic traffic bottleneck such as often occurs when access to the CBD is over a bridge or through a tunnel.

Fifthly, the cost of setting up a busway can be taken on and its benefits accrued in stepwise fashion. Initially, an express bus route in mixed freeway traffic could be introduced. Due to its higher speed, an express bus operation, perhaps with its own entry ramp as in the case of the Seattle Blue Streak, can deliver some portion of the increases in throughput, operating cost savings, energy savings and emission reductions promised by an exclusive right-of-way operation, compared to the cases of no bus service or of stop-and-go bus service on city streets. If rider response is favorable, steps may then be taken to reserve a lane for buses; later, construction of a busway could be considered as an alternative to adding a new auto lane or route.

Last but not least, busways make use of significant unused road capacity in the backhaul (non-peak) direction, and they can be implemented in nearly any city, since most cities have some such unused freeway capacity and at least one bus operator who would like to expand into potentially more profitable operations.

The overall impact of initiating busway operations may initially be very small from the point of view of the urban area as a whole. However, because the benefits increase proportionally with bus occupancy rates, increased benefits will be realized as occupancies rise. Two inexpensive, quickly implemented ways of encouraging higher occupancy, aside from measures to increase transit ridership in general (see 1.2, Attract Transit Ridership), are to provide adequate park-and-ride facilities and to speed bus flow on non-freeway portions of the route by introducing priority treatment of buses on city streets and arterials. Two longer range, more expensive approaches are to build exclusive rights-of-way and to provide more downtown terminal capacity.

The above evaluation applies to busway implementation when considered by itself. When considered in conjunction with other actions to divert commuters to transit and in a longer time frame, busways can offer additional advantages. First of all, they can be the first step toward dual-mode operation*. Once exclusive busways are provided, especially if on specially constructed, separate rights-of-way, it would not be difficult to install, in stages, electronic guidance and propulsion systems until complete automatic control of buses on the busway became possible. Thus dual mode, in its transit application, could be tested experimentally for short stretches at relatively low cost.

Secondly, implementing a busway can also be an important means of encouraging intermodal and interagency cooperation becuase it requires the cooperation of highway departments and transit authorities. For example, to set up the Lincoln Tunnel approach contraflow bus lane, joint action by one federal (U.S. Department of Transportation) and four state or regional agencies (New Jersey Turnpike Authority, New Jersey Department of Transportation, Port of New York Authority, Tri-State Regional Planning Commission) was required. In the case of the Shirley Highway busway, two U.S. Department of Transportation agencies, two state-level highway departments, two transportation commissions, three transit operators, and the local council of governments were involved. Similar agencies in the Los Angeles area cooperated to make the San Bernardino busway possible. Such a project could serve as a good exercise in regional transportation planning and provide a "foot in the door" for discussion of further efforts to integrate transportation modes.

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*See Volume 3 of this report, The Potential of Dual Mode.

IMPROVE URBAN GOODS MOVEMENT (2.2)

Introduction

Improving urban goods movement, which is tantamount to improving urban truck movement, is a relative newcomer to the group of strategies to improve vehicular flow. UMTA's first research report on the subject (28) dates from 1972, and a follow-on study effort was recently approved (November 1974) to provide additional required quantification. Thus it is not surprising that in some cases available information does not give very good answers to the types of questions now being asked. In the past, urban goods movement has been analyzed from the point of view of the economic efficiency of the trucking industry, or with the purpose of estimating trucks' roadway requirements and road user costs. The Highway Capacity Manual (122) provides useful empirical information on the effect of trucks on vehicle flow, and limited information is available on truck energy requirements and emission characteristics.

However, since truck traffic has typically been taken as given by traffic engineers, and improving truck movements has usually been used as a means of alleviating a very localized truck congestion problem or of improving truck industry profits, there is little "experience" with urban goods movement improvement and inadequate evidence to evaluate the impacts of the proposed actions on congestion, air pollution, and energy requirements. One researcher flatly states that, given the present state of research, it is not possible even to determine the orders of magnitude of pollution or the noise costs of urban delivery trucks (M. Masson, "Le Cout Social des Transport Urbains de Marchandises" [External cost of urban goods movement], in *Proceedings of the International Conference on Transportation Research*, pp. 197-202 [Chicago: Transportation Research Forum, 1974]).

Because of this lack of information, it is not possible to describe any experience with implementing this strategy and its actions or to review its impacts on goals as we have done for most other strategies. Instead, it seems more appropriate to present a brief review of the role of trucks in urban traffic and of what little is known about their effects on congestion, pollution, and energy consumption, and then to briefly present the policy actions suggested for improving current goods movement.

Effects of Urban Goods Movement

TRUCKS IN THE TRAFFIC STREAM. In general, trucks in the traffic stream contribute only marginally to urban congestion, but trucks double-parked or otherwise restricting traffic while loading and unloading can seriously reduce urban street capacity and increase congestion. Unfortunately, the truck parking problem has no good short-term solution.

Although vehicles registered as trucks account for 15 percent of vehicles in the urban traffic stream, for 20 percent on multilane highways, and for 23 percent on 2-lane roads, roughly 70 percent of these vehicles are light trucks which have no greater effect on congestion than passenger cars, although their emissions and fuel requirements are higher. The Highway Capacity Manual defines a truck for purposes of roadway capacity analysis as a vehicle with dual tires on one or more axles, or with more than 2 axles. This definition excludes 2-axle, 4-tire vehicles classified as trucks for registration purposes which have operating characteristics similar to those of a passenger car. This imlies that current traffic engineering experience has found that only larger truck vehicles have enough impact on traffic to warrant calculation of special adjustment factors when measuring existing road capacity or planning for new capacity.

Adopting this definition, we can see from the basic motor vehicle travel projections made for this study (see Volume 4, Table 1, p. 9) that urban truck traffic amounted to about 11-12 billion VMT annually over the 1968-71 period, compared to 440-530 billion annual urban auto VMT. Truck VMT amount to about 2 percent of total urban VMT, a share which changed little over the 1968-71 period. Annual increases in truck VMT average about 5 percent, compared to about 6 percent for auto. Urban truck VMT as a percentage of total urban VMT has, therefore, been decreasing over the past 20 years, while the auto VMT share has risen slightly. This national trend is also characteristic of most U.S. cities; a review of auto and truck trip projections in 13 cities showed that in all but one city (Denver), the projected annual increase in trips for trucks was projected to be less than or equal to that of autos (49, p. 178).

It is the fact that trucks are larger, slower vehicles that is responsible for their effect on urban traffic flow. The Highway Capacity Manual quantifies the reduction of highway capacity due to trucks in the traffic stream by a measure called the passenger car equivalent, defined as the number of passenger cars a truck effectively displaces in the traffic stream. On the level terrain usually found in cities, where truck speeds are not much different from car speeds, the passenger car equivalent is 2 for a multilane highway and between 2 and 3 on a 2-lane highway. In rolling or mountainous terrain, where the greatest difference occurs between normal auto and truck speeds, the passenger car equivalent can go as high as 5 or 10, but these conditions are not normally encountered in urban areas. The effect of trucks on capacity is calculated by multiplying the service volume of a road in terms of passenger cars by the factor (122, p. 102):

$$\frac{100}{100 - (\%\ \text{trucks})\ (1 - \text{passenger car equivalent})}$$

The percentage of trucks in the traffic flow does not usually exceed 20 percent and is less than 10 percent most of the time, so the value of this factor typically ranges from .95, when the passenger car equivalent is 2 and trucks make up 5 percent of the traffic flow, to .71, when the passenger car equivalent is 3 and trucks are 20 percent of traffic flow (see Table 2-9 below). This implies that the loss of service due to trucks in the traffic flow compared to a situation where there are only passenger cars ranges from 5 to 29 percent, with the latter volume being very unusual. Table 2-9 shows the way in which the values change with different assumptions regarding percent of trucks in the traffic flow and passenger car equivalents.

The Highway Capacity Manual sets 5 percent as a "normal" level of trucks in urban peak-period traffic flow (122, p. 142), implying a service volume of 95 percent of the no-truck level.* Therefore, the objective of improving urban goods movement from the congestion point of view should not be to eliminate trucks but to keep their numbers as a percent of traffic flow to less than

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*The effect of intercity buses is the same as that of trucks, according to the Highway Capacity Manual, but that of local transit buses can be greater, depending on the number of buses per hour, the number of lanes, and the placement of the bus stop. The local bus factor by which service must be adjusted to account for local bus traffic ranges from about .80 to 1.0 for 45 buses/hour (1.3 minute headways) on 2 lanes; it can go as low as .70 with higher bus volumes (90 buses/hour) (122, pp. 142-145).

Table 2-9. Effect of trucks on roadway service volumes.

Percent of trucks in traffic stream	Service volume with trucks as percent of service volume without trucks[1]		Percent loss of service due to trucks[2]	
	Passenger car equivalent:[3]		Passenger car equivalent:	
	2	3	2	3
5	95	91	5	9
10	91	83	9	17
15	87	77	13	23
20	83	71	17	29

[1] Equals 100/(100 - % trucks in traffic stream [1-passenger car equivalent]).

[2] Equals 100 minus service volume with trucks as percent of service volume without trucks.

[3] Number of cars effectively displaced by each truck in traffic stream. Typically equals 2 on multilane highways and between 2 and 3 on 2-lane highways.

or equal to 5 percent. This implies focusing on isolated road segments where truck volumes or truck passenger car equivalents are unusually high.

As far as pollutant emissions of trucks in the traffic stream are concerned, while medium and heavy trucks emit 1-1/2 to 2 times the pollutants per vehicle (CO, HC, NO_x) of autos under typical urban traffic conditions, it appears that trucks contribute proportionately less to urban air pollution than their share in the traffic flow would imply. Table 2-10 shows estimated urban truck emissions in 1970 compared to total 1969 figures. The urban truck emissions, based on VMT for both light and heavy-duty trucks, account for less than 10 percent of total motor vehicle emissions, only part of which occur in urban areas, although these trucks account for about 15 percent of urban traffic flow and about the same proportion of VMT.

The figures shown in the table underestimate truck emissions to the extent that they are based on (1) emissions of light-duty vehicles, which make up about 70 percent of the trucks in the traffic stream, and (2) speeds of 25 mph. A heavier, gasoline-powered truck will emit more pollutants than a light one, and any truck will emit more CO and HC at lower speeds. A truck averaging 15 mph, for example, emits 50 percent more CO and HC per mile than one averaging 25 mph. The figures overestimate emissions to the extent that they are based on emissions from gasoline-powered engines which are used in most light trucks.

Table 2-10. Estimate of air pollutant emissions attributable to trucks in urban areas.

	Emissions (millions of tons)				
	CO	NO_x	HC	SO_x	Particulates
Total[1]	151.5	23.8	35.4	33.4	35.2
Transportation[1]	111.5	11.2	19.8	1.1	0.8
Motor Vehicles[1]	98.0	8.7	17.1	0.3	0.4
Trucks[2]	8.9	0.8	1.1	0.02	0.03
% of total for motor vehicles	*9*	*9*	*7*	*7*	*7*

[1] 1969.
[2] 1970.

Source: Reference 28, pp. 54-56. Estimates of emissions are based on emission factors in units of grams per vehicle-mile at 25 mph for light-duty gasoline-powered vehicles in urban areas.

A diesel engine emits less CO and HC than a gasoline engine of the same weight, but more NO_x, SO_x, and particulates (28, pp. 56-57). For these reasons, the figures shown in Table 2-10 may not accurately represent urban truck emissions. A more accurate estimate would require data on truck population distribution and on per vehicle emissions by engine type or weight.

The relatively lesser importance of truck emissions implied by Table 2-10 is contradicted by other studies. The New York City Department of Air Resources, for example, estimates that two-thirds of all mobile source air pollution in downtown Manhattan is attributable to trucks (348). This discrepancy may well be a reflection of the effect of speed and congestion on truck emissions, since the 25 mph speed assumed in Table 2-10 is not typical of downtown Manhattan traffic flows.

As far as truck energy requirements, INTERPLAN found little information except for a statement by the DOT Urban Goods Task Force (348) that urban trucking is a major consumer of petroleum and appears quite inefficient in terms of energy utilization. Since the cost of fuel is only a small part of overall industry costs, there has not been much incentive for conservation. Further data on the subject are required.

Regardless of the data inadequacies, one firm statement about truck pollutant emissions and energy requirements can be made: both are very sensitive to urban congestion. Therefore, measures to increase truck speed, such as overall traffic control improvements (2.1.2) and, conceivably, truck sharing of dedicated bus lanes (2.1.4), would probably reduce truck emissions and fuel use more efficiently than efforts to reduce truck VMT alone.

PARKED TRUCKS. Curbside truck parking has a much greater effect on urban congestion than trucks in the traffic stream. Also, although the trucks do not emit pollutants or use energy if their engines are off while parked, the idle periods and slower speeds which they impose on delayed auto traffic result in an increase in pollutants emitted by non-truck traffic. The Highway Capacity Manual has no specific formula for estimating the effects of truck curbside activities, but rather suggests that for these and other traffic interruptions and interferences, a general problem area often encompassing several types of obstructions should be defined and known procedures and criteria, such as lost time and restricted lane width, should be adapted to these individual problems. As they point out, it is unlikely that meaningful individual factors for each type of interruption could be developed, since the impediments are generally related. Correcting one may be of little overall benefit if others, such as double parking by cars, midblock driveways, lack of channelization, and pedestrian interferences, are not also corrected (122, p. 326).

In a recent article by a French urban transport analyst, M. Masson (*op. cit.*), which presents results of French traffic research efforts to measure the congestion costs of obstructive truck parking, it is stated that in normal traffic flows, a parked truck obstructing traffic causes 3 to 5 times the reduction in service volume as a moving truck (p. 200). This article further points out that the external cost of delivering a truck shipment which includes the congestion cost is clearly higher than the economic cost of the goods delivery. In the example cited, a manual delivery involving traffic obstruction of a 100 kg (220 lbs.) load of goods in a 2-way, 2-lane street may imply an external cost 4 or 5 times as great as the economic cost paid by the client (25-30 Fr. vs 6-7 Fr., or about $5-6 vs $1.20-1.40). Furthermore there exists for each type of urban roadway a traffic threshold (vehicles/second) above which the effects of a parked truck in terms of minutes of delay increase rapidly. Length of time parked is another important variable affecting congestion costs.

The corrective policies for reducing these costs suggested by the French researcher are (pp. 201-202):

- Automation and containerization
- Increased shipment size
- Geographic specialization

These actions would, respectively, shorten delivery time, reduce delivery frequency, and reduce truck miles traveled. These and other measures whose purpose is essentially to make more efficient use of truck vehicles are closely related to the first and third of the three approaches to improving urban goods movement which INTERPLAN identified, consolidate routes and terminals (2.2.1), and combine passenger and freight movements (2.2.3). INTERPLAN's second action, separate goods and people movements (2.2.2), is more specifically directed at the cause of obstructive truck parking, i.e., the lack of adequate separate "rights-of-way" for off-street truck unloading. A summary of the information gathered on the impacts of these specific actions is given in Table 2-11 and brief descriptions of these actions follow.

Consolidate Routes and Terminals (2.2.1)

This action encompasses three specific suggested improvements: complete consolidation of routes and terminals; consolidation of routes alone; and improved dispatching techniques, which can be implemented by a single company as well as in cooperative consolidation ventures. The sources reviewed by INTERPLAN do not indicate much actual experience with these techniques. Most of the information that exists is based on qualitative projections on the effects of a consolidation effort in the Tri-State Region. The exceptions are an article by Richard de Neufville et al. on consolidation (70), which is based on computer simulations from actual data, and a brief description of actual British experience with improved computer and manual techniques in planning pickup and delivery (PUD) operations, reported on in Reference 239.

De Neufville's conclusion is that route and terminal consolidation by a group of trucking firms can lead to dramatic improvements in truck utilization and to an 80 percent reduction in total VMT, but that in most cases it is economically inefficient because of the high costs of consolidated terminal operations. Examples of completely consolidated operations include the United Parcel Service and municipal garbage collection. De Neufville also cites at

Table 2-11. Documented impact of strategies and actions on offsetting phenomena: Improve Urban Goods Movement (2.2).

PHENOMENA						COST ESTIMATES
1.0 Improved Auto Alternatives	2.0 Improved Vehicular Flow	3.0 Reduced Urban Auto Use	4.0 Reduced Urban Travel Demand	5.0 Reduced Vehicular Air Pollutant Emissions	6.0 Reduced Vehicular Petroleum Consumption	Highway, Auto
CONSOLIDATE ROUTES AND TERMINALS (2.2.1)						
Reference 239 Not applicable.	Can't pinpoint delays traceable to trucks (p.206).	Consolidating terminals could reduce truck VMT in model area (Manhattan) by 36% for terminal functions and 99% for line haul. Regionwide (Tri-State): 36% VMT reduction for terminal functions and 95% for line haul (p. 203). Improved dispatching has resulted in 0.8 - 20% reduction in truck VMT in British experience (p. 204).	Not mentioned.	Potentially helpful in decreasing emissions (p.205).	Not mentioned.	User: No change in direct cost for urban travelers from improved goods movements (p. 199). Industry: Estimated terminal lease costs per year: $100,000-$2,000,000, depending on area. Improved dispatching may also be prohibitively expensive; no figures given (p. 200). This is offset by the following projected savings to truckers from terminal consolidation: percent cost reduction in model area - 4% for terminal functions, 20% for line haul functions, 7% for billing costs. Percent regionwide cost reduction - 10% for terminal functions, 24% for line haul, 12% for billing costs, etc. (no total given) (p. 203). Actual British experience indicates savings from improved dispatching: 10% in reduced costs, 10-36% in reduced fleet vehicles (p. 204).
Reference 169 Not applicable.	Not mentioned.	VMT reduction due to reduction in vehicle trips.	Computer simulation showed an approximate 29% reduction in vehicle trips due to consolidation (p. 212).	Should be reduced; no figures.	Not mentioned.	Industry: In a computer simulation model designed to study the effects of consolidating delivery of two food categories in 19 convenience stores, it was found that savings from reduced driving time would amount to about $4,900 annually; cost savings to distributor (presumably through shorter processing time) would be around $52,500 annually, though the retailers would sustain slight cost increases (about $7,000/year) from increased time in order preparation (pp. 211-212).

Table 2-11. (continued)

PHENOMENA						COST ESTIMATES
1.0 Improved Auto Alternatives	2.0 Improved Vehicular Flow	3.0 Reduced Urban Auto Use	4.0 Reduced Urban Travel Demand	5.0 Reduced Vehicular Air Pollutant Emissions	6.0 Reduced Vehicular Petroleum Consumption	Highway, Auto
Reference 28 Not applicable.	Major relief of truck-induced congestion; no figures (p. 70).	Not mentioned.	Not mentioned.	Major reduction of truck air pollution; no figures (p. 70).	Freight consolidation offers the opportunity for technical innovations in power sources by concentration of capital (p. 75).	User: Citing a study by Lea, assuming that the cost of goods trucking amounts to approximately $280 per person annually in Canada (1966 figure for cities over 100,000) freight consolidation could save $25 per person annually by 2001, a 9% cost reduction. In addition, $90 per person annually might be saved by street and traffic improvements for goods movements, and $10 by improved facilities and vehicles (p. 44). Industry: Citing Wood study, consolidation system for 107 geographic clusters in Tri-State region would yield 12% cost reduction (p. 44). Freight consolidation requires a high investment cost (p. 71), but could reduce the number of vehicles required; no figures (p. 75).
Reference 117 Not applicable.	Not mentioned.	Not mentioned.	Not mentioned.	Not mentioned.	Not mentioned.	Industry: Tri-State region freight consolidation could result in annual operating savings of $95,000,000, including the costs of the additional terminals (p. 184). Hedges notes that 75% of the savings from urban goods improvements predicted in the Lea study are expected to accrue to the trucking industry (p. 192).

Table 2-11. (continued)

PHENOMENA						COST ESTIMATES
1.0 Improved Auto Alternatives	2.0 Improved Vehicular Flow	3.0 Reduced Urban Auto Use	4.0 Reduced Urban Travel Demand	5.0 Reduced Vehicular Air Pollutant Emissions	6.0 Reduced Vehicular Petroleum Consumption	Highway, Auto
Reference 70						
			Terminal Consolidation			
Not applicable.	Unlikely to make a real dent in vehicular congestion (p. 22).	Reduce truck-miles per day about 80% total (p. 28).	Not mentioned.	Less pollution; no figures (p. 2). Not a useful tool for reducing air pollution in downtown areas, since most savings in mileage do not occur in PUD portion, and PUD operations may not involve much downtown mileage (p. 17).	Significant fuel savings; no figures (p. 2).	Terminal consolidation can be cost effective for very limited, though important, forms of goods movements, e.g., garbage collection, to which it has already been applied where feasible. Significant reductions in cost of transport can be expected. These are offset however by high operating costs. Consolidation terminal costs: small shipments, $1 a package or $80 a ton; 500-lb. packages - $10 a ton; several ton bulk shipments - less than $1 a ton (p. 11). Terminal consolidation is more desirable when main terminals are far from PUD area, and as the size of shipments increases (pp. 19-20).
			Route Consolidation			
Not applicable.	Unlikely to make a real dent in vehicular congestion (p. 22).	Reduce total truck-miles per day about 50% (including line haul and PUD operation (p. 28).	Not mentioned.	Less pollution; no figures (p. 9).	Not mentioned.	Geographic sorting of shipments may be expensive and time-consuming for carriers; route consolidation most desirable for small group of carriers (p. 9). Could reduce the cost per ton shipped from about $100 to approximately $60 for model used (p. 29).
			SEPARATE GOODS AND PEOPLE MOVEMENTS (2.2.2)			
Reference 239 Not applicable.	Can't pinpoint delays traceable to trucks (p.206).	Not mentioned.	Not mentioned.	Potentially helpful in decreasing emissions (p.205).	Not mentioned.	Government: Minor implementation and regulatory costs; may be offset by fines (p. 200). Industry: Costs to truckers could range from a decrease of .5¢/100 lbs. (for prohibiting movement in CBD during peak periods) to an increase of 1.75¢/100 lbs. (for restricting terminal location); 1966 figures (p.202).

Table 2-11. (continued)

PHENOMENA						COST ESTIMATES
1.0 Improved Auto Alternatives	2.0 Improved Vehicular Flow	3.0 Reduced Urban Auto Use	4.0 Reduced Urban Travel Demand	5.0 Reduced Vehicular Air Pollutant Emissions	6.0 Reduced Vehicular Petroleum Consumption	Highway, Auto
Reference 28						
Spatial Separation (offstreet loading; freight lanes and tunnels)						
Not applicable.	Major relief of truck-induced congestion; no figures (p. 70).	New Haven, Conn. truck freight tunnel, opened in 1963, has had steadily increased use. Street deliveries now negligible (p. 91).	Not mentioned.	Little or no reduction in truck air pollution; no figures.	Not mentioned.	Government and Business: Costs of tunnels may be prohibitive, except in conjunction with large-scale urban development (p. 93). Cost of off-street loading to business will be high. Industry: Costs could be modestly reduced (freight lanes and tunnels) or increased (off-street loading).
Temporal Separation						
Not applicable.	Major relief of truck-induced congestion; no figures (p. 70).	Not mentioned.	Not mentioned.	No relief of truck air pollution (p. 70).	Not mentioned.	Industry: Low investment cost (p. 71). Probable minor cost reduction (p. 70). In an actual 6-month experiment with night deliveries in London in 1968, delivery costs rose approximately 34%, and costs to receivers rose about 110% (p. 97). This may have been due to the limited number of businesses participating and the limited duration of the experiment.
Urban Fringe Terminals						
Not applicable.	Modest relief of truck-induced congestion; no figures (p. 70).	Not mentioned.	Not mentioned.	Modest reduction of truck air pollution (p. 70).	Not mentioned.	Industry: Modest cost reduction; no figures (p. 70). Modest investment costs (p. 71).
Automated Goods Movement Systems						
Not applicable.	Major relief of truck-induced congestion; no figures (p. 70).	Not mentioned.	Not mentioned.	Major reduction of truck air pollution (p. 70).	Not mentioned.	Industry: Negative impact on costs; no figures (p. 70). High investment costs (p. 71).

Table 2-11. (continued)

PHENOMENA						COST ESTIMATES
1.0 Improved Auto Alternatives	2.0 Improved Vehicular Flow	3.0 Reduced Urban Auto Use	4.0 Reduced Urban Travel Demand	5.0 Reduced Vehicular Air Pollutant Emissions	6.0 Reduced Vehicular Petroleum Consumption	Highway, Auto
Reference 28		COMBINE PASSENGER AND FREIGHT MOVEMENTS (2.2.3)				
Not applicable.	Major relief of truck-induced congestion; no figures (p. 70).	Not mentioned.	Not mentioned.	Major relief of truck air pollution; no figures (p. 70).	Not mentioned.	Modest reduction in costs; no figures (p. 70). Modest investment costs (p. 71). Truck use of busways may be partially financed with highway revenues (p. 93). Cost reduction for both passenger and freight movements by faster amortization of capital investment costs (p. 110). Carrying freight might make rapid transit economically viable in places where passenger demand alone cannot justify it (p. 113).

least two examples of consolidated terminals in New York City: National New York Packing in the garment district, and Rydair, which handles air cargo for 22 carriers. It should be noted that these are rather specialized areas of urban goods movement, and that Rydair, from which most of the data was obtained, is not properly speaking a good example of consolidation because it is a single company and not a cooperative venture.

One less than successful example of consolidation cited by several reports is the New York Port Authority truck terminal, which opened in 1949. Over-the-road trucks were to bring their loads to the terminal, and local PUD operators were to handle shipments to and from the terminal. At the time, it was predicted that the terminal would lead to a 25 percent reduction of movement in the city by over-the-road carriers handling less than full truck loads. This prediction proved unrealistic. The shippers who participated received complaints from customers about poor service, and felt they were at a competitive disadvantage vis-à-vis shippers not participating. Many carriers who at first agreed to participate either eventually withdrew or modified their agreement so that they had more individual control over the pickup and delivery of their freight. The problem was generally felt to be lack of coordination and division of responsibility between the line-haul, PUD, and terminal functions.

Route consolidation alone would offer greatly improved efficiency, possibly reducing VMT by 50 percent, according to de Neufville, without the high implementation costs required for consolidated terminals. It is, however, already in use where practicable, i.e., for delivery of mail, newspapers, and groceries, but these are specialized activities dealing with low-bulk goods, unlike the majority of urban goods movements. INTERPLAN found no examples of route consolidation among private, competing carriers.

Consolidation, then, appears to have great potential for improved truck efficiency, reduction in truck VMT, and therefore reductions in air pollution and energy consumption. However, it seems unsuitable for some types of goods movements and hard to implement in other areas which de Neufville identifies as potentially ripe for consolidation activities, e.g., the garment industry and air freight. He concludes that consolidation should be encouraged where conditions warrant and where cooperative handling of goods does not already exist. De Neufville's conclusion is that programs of consolidation of urban goods movements are unlikely to make a real dent in vehicular congestion and pollution in the city (70, p. 22).

One technique which is not often mentioned but which could offer some of the same benefits as consolidation and could be implemented independently is the use of improved dispatching techniques. The results of British experimentation in this field seem impressive: a 10-36 percent savings in vehicles needed; a 10 percent reduction in operating costs in at least one case; and 1-20 percent decrease in VMT (239, p. 204). Such techniques would, however, only be applicable to companies having medium to large fleets, while it is estimated that 83 percent of all trucks in local operations in the United States are in fleets of one to five trucks (28).

Separate Goods and People Movements (2.2.2)

Passenger and cargo movements can be separated temporally or spatially. Suggestions for temporal separation include restricting truck movements in cities during peak periods and proposals for night deliveries. It is generally felt that there is not much room for improvement here, since most cities already regulate truck delivery times to some extent, and since trucks do not appear to be major contributors to peak-period congestion in any case. Night deliveries are felt to be infeasible in some cases because of union opposition to changes in working hours. Also, an experiment in London in 1968 (Operation Moondrop) showed that night delivery costs rose approximately 34 percent while costs to receivers rose approximately 110 percent due to the need for shops to have someone on hand to receive the goods at night (239).

On the other hand, in cases where night delivery is practical and acceptable, its use does make a positive contribution to reducing congestion which could be important in specific downtown areas. The importance of this contribution depends on the degree of participation by businesses and on the length of the adjustment period. It has been pointed out that the 1968 London experiment may not have been a fair test of the techniques because not enough businesses participated for the effects to be apparent, and because the 6-month duration of the experiment did not allow sufficient time to work out communications problems. Furthermore, although night delivery does not in itself reduce VMT, and therefore would not directly reduce truck emissions or fuel consumption, emissions and fuel use would be lowered indirectly due to the higher speeds and less frequent delays experienced while driving after hours. The time gained by being able to deliver more quickly, moreover, constitutes an important gain to the trucking firm.

If the labor and security problems can be resolved, therefore, a night delivery schedule seems a useful means of getting trucks off the streets in older areas where off-street unloading space is not available and where daytime congestion due to truck parking is a problem. A recent article in The Economist reports that night delivery has been quietly increasing in Britain, citing the example of a fish delivery service organized by the national road haulage corporation and of a grocery chain which switched to night delivery. In both cases, a doorkey is the key to success: the truck driver carries a key either to the delivery area itself or to specially secured containers or keyrooms which are locked from both sides. This obviates the necessity of keeping someone on hand in the shops to receive goods after business hours. The article also stated that many trucking firms had found the energy crisis a good excuse for specifying certain days for delivery, thereby reducing the frequency of deliveries and necessitating better planning by receivers. (Richard Casement, "Freight Transport: A Survey," The Economist, 16 November 1974, special section.)

Suggestions for the spatial separation of goods and passenger movements include urban fringe terminals, offstreet loading and unloading areas, truck freight tunnels, and automated underground conveyor systems. Here again it is generally agreed that these facilities are already being adopted to the extent feasible and that major further improvements are possible only in the context of major urban redevelopment projects or construction of new towns. The provision of sufficient offstreet loading and unloading capacity should be required in all new developments and in the redevelopment of older buildings within the CBD; it is sometimes suggested that this be encouraged by higher taxes on buildings not providing such capacity, or by other legal and economic incentives. These incentives are necessary because loading space is considered to be non-revenue producing, and builders therefore tend to minimize it. The Battelle report for DOT (28) notes that offstreet loading facilities may not reduce congestion if other vehicles proceed to fill up the space vacated by trucks. Stricter enforcement of curbspace and double parking regulations would therefore be required even if truck deliveries were moved off the street.

An underground truck freight tunnel constructed as part of a redevelopment effort in New Haven, Connecticut, which opened in 1963, has successfully reduced street deliveries to a negligible amount (28). Similar tunnels are also proposed as part of redevelopment projects in Dallas and Fort Worth. This type of facility, however, is economically feasible only in special applications.

Automated underground conveyor systems for movement of trash have been implemented in a new town in Sweden, in Disneyworld, and on Welfare Island in New York. It would most likely be impractical to incorporate them in many older cities. Underground conveyor systems for goods movements, in addition to being very costly, increase handling requirements, since it is uneconomical for such systems to extend directly to every origin and destination. Conveyor systems seem to be feasible only for limited types of commodities (i.e., trash) or when applied to a limited area, for example, between terminals in a freight consolidation system or beneath a local major activity center.

Spatial separation, except for such automated systems, might be helpful in reducing localized congestion, but its effects on air pollution and energy consumption would be restricted to the indirect reductions due to better auto traffic movement.

Combine Passenger and Freight Movements (2.2.3)

The last major group of suggested improvements would combine passenger and freight movements by allowing truck use of reserved bus lanes; using transit buses and rapid rail to carry freight, especially during off-peak hours when they normally carry less than capacity loads; or implementing new systems such as PRT designed to carry passengers and freight together or in separate modules. As yet, there have been no demonstrations of any of these possibilities, though they are widely suggested. In addition to reducing the number of trucks involved in goods movement, such joint use of facilities is predicted to make better use of capital investments in transit facilities, and in some cases might justify investment in rapid transit when passenger demand alone could not. This prediction assumes, however, that major institutional and technical obstacles could be overcome, such as the inevitable differences between economic labor requirements and union demands, and the fact that goods movements generally have much more dispersed origins and destinations than passenger movements.

One DOT researcher, Charles Hedges, notes, however, that an UMTA technical grant has concluded that it would be feasible to develop a joint goods-passenger system in the new town of Columbia, Maryland, which "would accommodate both people and goods on a reserved right-of-way within the complex of the town. The system would be demand activated like the 'dial-a-bus,' but would have replaceable cabs which could be used either for passengers or for freight, depending upon the delivery requirement" (117). Another recent proposal in Public Transit Report suggests a "Metrofreight" system for Washington, D.C. using buses, subways and commuter trains to carry freight (Public Transit Report, 31 March 1974). This would require a basic, easily-switchable chassis which could carry passengers or freight containers. System proponents feel that the problems can be overcome by "sophisticated freight moving, security, communications, accounting and billing" and suggest that the project be financed by bonds issued to the public which would be redeemable in the form of transportation of people or freight.

Techniques for combining goods and passenger movements would be most applicable in small or medium-sized cities and not in large cities where transit capacities are already severely strained. Careful studies would have to be made to identify the routes for which such joint haulage would be beneficial so that, for example, trucks using reserved bus lanes would not interfere with express buses. More practical research is required in this area before any general conclusions regarding applicability can be drawn.

Overall Evaluation

Except in specific congestion bottleneck areas, improving urban goods movement is likely to have a minor effect on congestion, air quality and energy use, though it may result in more efficient use of goods movement facilities and vehicles and in savings to the industry and to consumers. Exceptions may be very important in individual cities, and these should receive special attention, as in the case of the New York City garment district being studied by DOT. On the whole, however, goods movement is felt to be a minor issue on the national policy level, primarily for the following four reasons.

Firstly, no one really knows to what extent urban goods movement contributes to traffic congestion, but the indications are that the contribution is not significant. The R. H. Pratt Associates study comments that trucks, even allowing for their greater size, do not constitute a significant enough portion of urban traffic that their removal would greatly improve other vehicular flow (239, p. 208). The Battelle Institute cautions that because the most extensive and in-depth knowledge of urban goods movement to date is based on the Tri-state regional study there is a danger that urban goods movements will be viewed in this perspective on a national level. Such a view would be erroneous because goods movement in the New York area represents a singular situation characterized by large scale of goods movements, non-typical street patterns with many narrow streets and streets with no alleys, and high traffic densities. At present there is not sufficient information to determine whether the same kinds of problems exist or will arise in enough cities to warrant broad public action to alter goods movement patterns outside New York and a few other large old cities.

Secondly, the limitations of the proposed improvements include the high cost of some of the more comprehensive suggestions (consolidation terminals, truck freight tunnels, automated systems); institutional obstacles such as union resistance to changes in working hours and industry opposition to more temporal and spatial restrictions; and the fact that many suggestions have limited applicability. There is still not enough empirical data on the effectiveness of these strategies, and some are already being utilized to the extent that is economically or politically feasible (e.g., temporal and spatial restrictions on PUD operations). In any case, major improvement in urban goods movement will occur in an evolutionary fashion and not in response to short-term policies.

Thirdly, it is noted that trucks form a decreasing proportion of vehicles in the urban traffic stream, and automobiles make up by far the major element in both actual numbers and percentages. It would therefore probably be more productive to concentrate on other more generally applicable strategies which would improve urban goods movement indirectly while improving the overall flow of traffic and reducing *auto* pollutant emissions and energy consumption. After all, truck movement is more a victim of auto congestion that the other way around: the New York Trucking Association reported in 1971 that an average truck operating in mid-town Manhattan lost four hours in earning time daily because of congestion (117). It is not uncommon for trucks to spend up to 16 percent of travel time in traffic delays (263). Fuel consumption of trucks is highest in the CBD, where stops due to congestion occur 3 times more often than in the suburbs. According to 1968 figures, congestion adds 82¢ per mile to the cost of running a truck in the CBD over the basic cost of $1.24 per mile which obtains in the urban fringe (348). While truck-related air pollution and energy consumption could in the long run be reduced by following such strategies as increased consolidation to reduce VMT, capital intensive measures such as automated goods movement systems, or as yet untried techniques such as combined passenger-freight systems, strategies for developing more efficient engines (strategy 5.3), better alternative power sources (strategy 6.3), and for conserving petroleum (strategy 6.1) would have a direct impact on both auto and truck emissions and fuel use.

Fourthly and lastly, the federal government seems to have limited authority to intervene in the urban goods industry. The industry is very fragmented and different segments are regulated by different agencies at different levels of government from federal to local. Some regulatory bodies, such as the ICC and CAB, have sometimes established conflicting policies which lead to further inefficiencies, such as their overlapping and often confusing definition of "commercial zones". UMTA can serve an important function by sponsoring more research and supporting individual demonstration projects to obtain needed data on the feasibility and effectiveness of the proposed actions, and eventually by establishing legal, pricing and other non-hardware incentives to stimulate the industry to implement promising techniques.

IMPROVE AIRPORT ACCESS (2.3)

Introduction

As in the case of improving urban goods movement (2.2), improving airport access is not a strategy which contributes significantly to overall reduction of urban congestion, air pollution, and energy consumption, but rather one which, while of minor importance on a national level, may be of major importance to an individual city. It is for this reason that this strategy has been included in the study. Following a brief review of the role of airport travel in urban travel, the two actions suggested for reducing auto travel to airports, improving public transport to airports (3.2.1), and increasing short-haul intercity rail alternatives (2.3.2), are reviewed. The discussion closes with an overall evaluation of both actions.

Effect of Airport Travel

At present, air travel is the largest public carrier of intercity passenger trips, and it is projected to continue growing rapidly. In 1955 domestic airlines carried 22.4 billion passenger miles; in 1970 they were responsible for 109.6 billion passenger miles. Passenger activity is predicted to more than double by 1980; projections range from 231.4 to 258.5 billion passenger miles (147, p. 3-13). Estimated current total enplanements at U.S. airports are 200 million per year. For the past 15 to 20 years, the enplanement growth rate has been around 9 percent annually (229, p. 4), although it dropped to about 3.5 percent in 1974 (Los Angeles Times, 11 November 1974).

Such rapid growth has created problems for airports, many of which are suffering from congestion on both the airside and landside. Though this is a matter of genuine concern for the airports, it is not a major urban transportation problem. In the context of this study, we are interested only in the impact that airport trips have on urban traffic congestion, and, to some degree, on air pollution and energy consumption.

An airport can be one of the largest single trip generators in an urban area. Total travel to and from airports by area residents alone, not counting visitor trips, ranged up to 20,000 trips per day in 1966, according to the National Cooperative Highway Research Program report, Urban Travel Patterns to

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Airports, Shopping Centers, and Industrial Plants (155), which is a major source of data on airport travel. However, airport trips usually do not account for more than 1 percent of average weekday travel in an urban area. Quoting from the report:

> "Of the airports sampled, Chicago Midway generates the most travel--approximately 220,000 vehicle-miles. Yet this is only 0.72% of the 31 million vehicle-miles of travel (VMT) in that study area on a typical weekday. Every airport considered accounted for less than 2% of the total travel in its study area, ranging from 0.26% (San Diego) to 1.68% (Atlanta).
>
> "Traffic impact becomes significant only when considering the airport traffic zone itself. In Pittsburgh, for example, it was found that the daily airport VMT accounted for about 32% of the daily total traffic zone VMT. ...
>
> "To take the comparison further, airport travel accounted for about 40% of the total travel on the main airport access road (Airport Parkway) on a daily basis. Again, the percentage was somewhat higher during the afternoon peak hour. Fortunately, in 1958 there was not a difficult capacity problem on this main access road. Its four 12-ft lanes carried about 20,000 vehicles a day near the airport entrance. But consider the capacity used up at this point by airport tripmakers alone: on a 24-hr basis, about 25%; on an afternoon peak-hour basis, about 47%" (155, pp. 30-31).

The degree to which airport travel contributes to urban traffic congestion is very site-specific and depends on several factors. Airports located close to a city center contribute more to traffic congestion because there is a greater use of the facility by non-airport-bound traffic. At Chicago's Midway and San Diego's Lindbergh Airports, for example, where terminal buildings directly abut major arterial streets carrying mixed traffic through dense urban development, the impact of airport trip generation on the highway network is much greater than in Pittsburgh, where the airport is far from downtown (155, p. 31). This phenomenon suggests that airport access should be less of a problem in the future, since the trend is to build airports at relatively great distances from the CBD in areas that are not yet built up.

Another factor that must be considered in determining the impact an airport will have on highway facilities is the proportion of passengers using the airport who are making interairline transfers. For instance, Chicago's O'Hare airport has the greatest overall number of annual air passengers, but 50 percent of these are merely transferring and flying on. When adjusted for transfers, Los Angeles has the greatest demand for landside capacity of any airport in the top 20 (229, p. 12).

The airport congestion problem is characterized by the fact that there are high concentrations of enplanements at a small number of airports. Fifteen U.S. airports are now responsible for 56 percent of total enplanements. According to a recent report, five of these 15 airports are currently experiencing serious to critical landside congestion (229, p. 6). These are: Chicago, Los Angeles, Kennedy, LaGuardia, and San Francisco. The remaining 10 (Atlanta, Miami, Dallas, Washington, D.C., Boston, Denver, Detroit, Newark, Philadelphia, and Pittsburgh) are also experiencing some congestion and delay. This information supports the estimate of an earlier report (1968) which found that airport access improvements (specifically, airport-CBD links) would be applicable in 20 major cities (63, p. 8).

Two congestion-related characteristics of airport trips are that most trips are made by car and that their peak times correspond with those of other trips. All airport trips in the U.S. are made by motor vehicle except in Boston and Cleveland, where the airports are served by rail links, and in Chicago, Los Angeles and New York City, which have passenger helicopter service to the airport (229, p. 13). The average distribution of modes for passenger arrivals at major U.S. airports is as follows (229, p. 13): 70 percent private auto, 13 percent bus, 10 percent taxi, 4 percent limousines, and 3 percent trucks. These proportions vary from airport to airport. At New York City airports, for example, private autos account for only 40 percent of all trips and taxis for 30 percent. In Philadelphia, the percentages are automobile, 60.3; transit, 20.9; taxi, 16.7 (57, p. 35). The above figures include airport trips of both residents and non-residents (out-of-town visitors). The former are much more auto-oriented than the latter: it is estimated that 90 percent of airport trips by residents of an urban area are made by automobile (155).

While airports are round-the-clock trip generators, airport trips tend to peak at the same time as other urban travel, due to the importance of airport work trips. Airport trips made by air travelers (see Figure 2-5) show no strong peaking characteristics and stay within the same range between 7 A.M.

and 10 P.M., while airport work trips tend to have "industrial peaks" in the early morning and mid-afternoon, and social and recreational airport trips are usually made in the evenings. As a result, the composite peak for all types of airport trips usually occurs in the late afternoon (see Figure 2-6). Since both of these figures are based on home interviews with urban residents, visitor airport trips are not included, but there seems little reason to believe that the distribution over time of these trips would be much different than for urban resident airport trips for air travel.

The predicted doubling of air travel by 1980 indicates that there will be a rapid growth in passenger trips to airports. Reference 155 suggests that vehicle movements at airports are likely to increase faster than passenger movements for the following reasons:

- Rapid growth in airport freight is predicted, meaning that more trucks will need airport access. Currently, trucks account for only about 5 percent of airport trips.
- The increasing number of 2-car families will probably mean a decline in the number of taxi and transit trips to airports.
- The number of passengers per automobile (average occupancy) will probably continue to decrease.
- Businesses and industries that generate air travel will become increasingly dispersed throughout the urban area, and will not be as concentrated in the CBD as at present. Therefore, transit and taxis will not be used as much for trips to airports.

These trends suggest that unless something is done to improve access to major airports, congestion in and around these airports will increase over the next five years. The two actions which we consider are to improve transit service to airports (2.3.1) in order to discourage airport auto trips, and to increase short-haul intercity transportation alternatives (2.3.2) in order to eliminate the need for some airport trips altogether.

Improve Public Transport to Airports (2.3.1)

When airport access routes begin to be congested, the first suggestion is naturally to expand the existing highway's capacity or to build a new limited access highway, such as the one to Dulles Airport near Washington, D.C. The highway approach dominates in a package of improvements proposed for the Los Angeles airport to relieve existing congestion and prevent expected future congestion. Planning efforts call for traffic metering, overpasses from remote

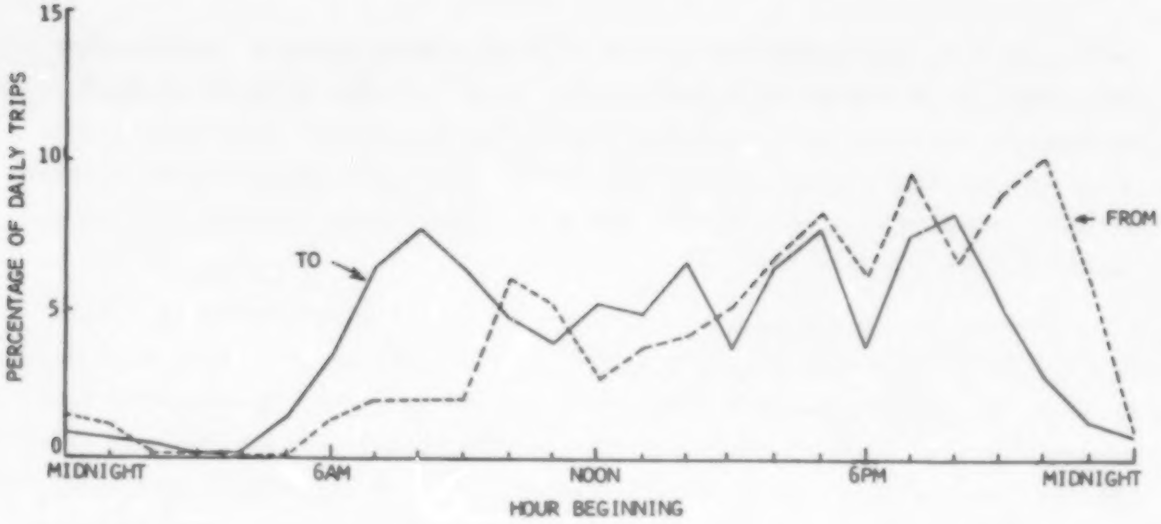

Figure 2-5. Urban resident airport trips for air travel, composite curve for selected airports.

Source: Reference 155, p. 15.

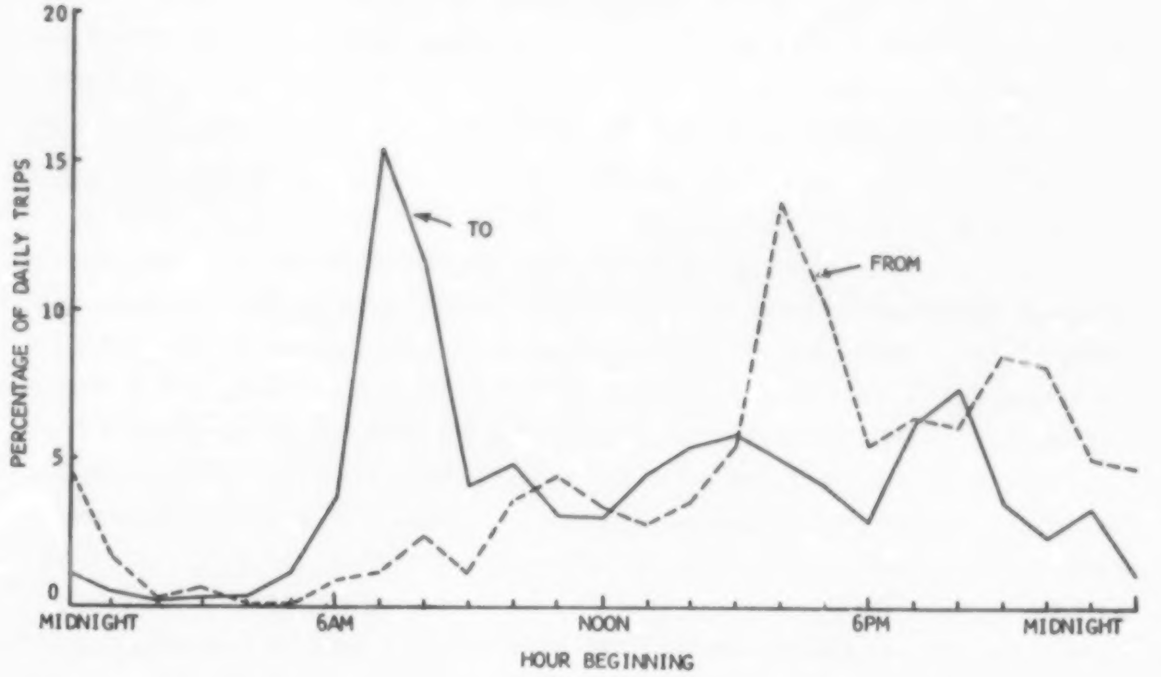

Figure 2-6. Urban resident airport trips for all purposes, composite curve for selected airports.

Source: Reference 155, p. 16

parking lots to the airport, and a new arterial roadway to carry traffic from the Santa Monica Freeway to a new transfer center in East Westchester where passengers, visitors, and greeters would be carried by a new mechanical people mover to satellite terminals (229, pp. 36-37). The plans also include an inter-airport busway linking the Van Nuys and L.A. International Airports, but most new facilities are auto-oriented.

However, as Kenneth E. Cook remarked in a recent Highway Research Record article (56), it is becoming increasingly evident that in many cities it will be financially and socially impossible to provide adequate freeway access to, or adequate parking facilities at, airports for increased numbers of private autos. The most obvious short- to medium-term answer to relieving airport congestion seems to be expanding airport transit service. Improved transit access to airports could not only encourage a shift away from private autos for airport trips but also discourage wellwishers from accompanying travelers all the way to the airport, thereby eliminating some airport trips entirely (56).

Various transit services have been proposed: bus and limousine service from downtown or satellite terminals with parking areas, dial-a-ride, rapid rail links, and new systems such as personal rapid transit (PRT) and tracked air cushion vehicles (TACV). The controversy at the moment seems to center around the choice-of-mode issue, i.e., whether express bus service is adequate and whether or not it is economically feasible to build rapid rail or advanced system links to airports.

EXPERIENCE AND PROPOSALS

Bus. Many airports are served by downtown express buses and limousines, although INTERPLAN knows of no airport with express service from outlying fringe parking lots. One recently implemented airport access system which appears to be successful is the Chicago O'Harexpress bus, which was initiated with the assistance of an UMTA demonstration grant. The bus provides 24-hour express service between the airport and a Chicago rapid transit station. The service was designed with the goal of providing a means of airport access for low-income residents in order to broaden their job opportunities. It has been judged successful in this regard, and has provided an unexpected bonus: air travelers have found the service convenient, and comprise about half of the passengers (1,400 daily riders overall in 1971). In a survey taken in 1970, it was found that "90 percent of the commuters and 60 percent of the air travelers who traveled to the airport before operation of the O'Harexpress did so by automobile. Thus, the diversion from automobile to transit tends to reduce highway congestion to the benefit of all Chicagoans" (327, pp. I-3, I-4).

The proposed busway to the Kansas City International Airport, described in a 1970 Highway Research Record article (129), would have carried the express bus concept one step further by providing an exclusive right-of-way. A new Kansas City International Airport, 19 miles from the CBD, was scheduled to open in 1971 and was planned to be a major regional airport. Airport officials felt that innovative technologies such as monorail or high-speed rail systems were potentially applicable but ruled them out because none of the systems had been adequately developed or tested and because there would not be enough demand to justify this type of airport link until several years after the airport had been in operation. Since it was agreed that some sort of transit system should be operational by 1975, an interim solution was chosen: a busway on a separate right-of-way. Plans were made to obtain the necessary 2-lane right-of-way immediately along the highway corridor, with the provision that if demand for airport access grew beyond the capacity of the busway, the right-of-way would be converted for use by a more advanced transit system, such as TACV.

The busway as planned would be used by high-speed express buses carrying air travelers between the airport and the CBD (estimated 15-minute rush-hour trip, compared to 45 minutes by highway during peak periods), as well as regular transit buses for airport employees or for persons commuting from the airport area to the CBD. The system was also designed to provide grade-separated access within the airport to the terminal buildings, which would permit passengers transferring between airlines to travel quickly between terminals. The total cost for the busway, including acquisition of right-of-way and a parking garage for 1,500 cars at the downtown terminal, was estimated at $30 million. Unfortunately, an $8 million bond issue which would have provided the local share of the cost was turned down by the voters.

Rail. Airport rail links, like urban rail service in general, are more common in Europe than in the U.S. London's Gatwick Airport, which is located 27 miles south of the city, is one of the few European airports located on a regional, as opposed to a municipal, rail line. This line takes passengers from the airport to downtown Victoria Station in 40 minutes, and it is reported that 40 percent of air passengers use the railroad for access (127). Brussels, Belgium, has rail service to the airport from a downtown terminal where passengers can check in and then board specially designed luxury rail cars for the ride. However, there has been very low utilization of the service, and the check-in service at the city terminal may be discontinued. It is felt that the Brussels experience is influenced by the fact that the distance to the airport is relatively short (about 10 miles) and that the highway airport access routes are not usually very congested (1).

Boston and Cleveland are the only U.S. cities which currently provide some sort of rail airport access, although UMTA is currently contemplating rail links to the O'Hare, Newark, Philadelphia, and New York City airports (229, p. 26). In Boston, a subway line is located near the airport, but passengers must transfer to a shuttle bus to reach the air terminal. Because of this inconvenience, plus the fact that the airport subway line lacks good connections with the rest of the subway system, the percent of airport trips using the subway as access has remained relatively constant at 5 percent (205).

In Cleveland, a city rapid rail line was extended in the late 1960s to the airport, which is relatively small, ranking 17th in the number of enplaned passengers. The rail link provides travel times of 25 minutes to the airport from the CBD; highway access times are usually just as fast or faster, except during peak hours when there may be 10 to 15 minute delays. Prior to the rail service, air passenger access was provided primarily by car (62 percent), limousine (13 percent), taxi and rental cars (20 percent) and public bus (1 percent). The rail link now carries 15 percent of air passengers, and there has been a 35 percent drop in air travelers' use of private and rental cars to get to the airport. Ridership to and from the airport on the rail line has leveled off to slightly less than 2,000 passengers per day (366, p. 23). Most airport rail trips are made by air travelers (60 percent) and their friends (10 percent). Casual visitors make up 20 percent of trips and airport employees 6.5 percent. The rail line is estimated to have captured 50 percent of the total air traveler market in the area served by the Cleveland rapid transit system. Forty percent of air travelers from the CBD use the rail access.

An important feature of the Cleveland airport link is that it is an integral part of a larger transit system. Passengers not only use the rapid rail line from the CBD to the airport, they often ride it all the way to or from their suburban residences near the transit line. As a result, less parking is needed downtown and at the airport. Furthermore, the opening of the rail line also had a beneficial impact on the transit system as a whole. It increased transit ridership by 7 percent, a percentage which is expected to grow as air traffic grows. Also, much travel to and from the airport is during offpeak and weekend hours, utilizing what would otherwise be unused capacity. Since transit ridership peaking is therefore reduced, the transit system can operate more efficiently and hopefully keep fares down for all riders (366).

Reference 56 draws several conclusions from the above-mentioned experience. Investment in a totally new transit system to an airport would probably not be justifiable in most cases, though short spurs to the airport that would connect with existing transit systems (such as in Cleveland) might, occasionally. Rail links are cost-effective only in dense linear corridors, and there are relatively few cities with both the population density and the airport usage level high enough to warrant their construction. Even in New York City, a proposed subway spur to Kennedy Airport is forecast to carry only 2,500 passengers during peak hours, while normal subway lines have the capacity for 10 times as many. Figures for London's Heathrow Airport estimate that if links from existing regional and rapid rail lines were established to the airport, by 1980 the links could carry 2,000 passengers per hour in each direction, which is only 4,000 passengers per hour total, still quite a bit below the potential capacity of rail systems (127). And most rail airport access proposals are for links between the airport and the CBD, which is not typically a high-density corridor. The low passenger forecast for the Kennedy Airport spur in New York City, with its high core density and high airport usage, strongly implies that the feasibility of rail airport access is remote for the vast majority of U.S. cities (56, p. 3).

Advanced Systems. The use of a TACV system for airport access has been proposed by Aerotrain of France, among others, which is in the process of developing prototype TACVs. Aerotrain foresees using a TACV with routine 125-mph speeds to serve airports located 6 to 60 miles from the CBD. Use of a

TACV to Paris' DeGaulle Airport would, it was estimated in 1966, cut travel time from the current 20-30 minutes to 6-7 minutes (363). Such a system could increase the use of some large airports which are now less popular because of their distance from the CBD, such as Dulles and Friendship Airports near Washington, D.C. Unfortunately, during the last budget squeeze in France, funding for the Aerotrain TACV system was cancelled;as of December 1974, the project has been suspended.

A TACV system was also proposed for the Los Angeles International Airport (LAX). According to a June 4, 1970 DOT news release, the TACV system was to be in use at LAX in late 1972. It was to run on an elevated guideway from the airport along the San Diego Freeway to the San Fernando Valley with an intermediate station at UCLA, a route length of 16.3 miles. Passengers could be checked in at the San Fernando and UCLA stations. The TACV was to be powered by linear induction motors, which are claimed to be pollution-free at the guideway.

In 1971, another report (259) described this proposed system, noting that the average speed was calculated to be 89 mph and travel time 11 minutes. The initial projected ridership was 5.2 million with 8.0 million annual riders after the fifth year, 90 percent of whom would be airline passengers. This ridership represents 23 percent of the market share in the study area, which contains 29 percent of LAX air passengers excluding employees or visitors. Total system cost was estimated to be $135 million. By the fifth year, the system was predicted to show an annual profit of $2.4 million. INTERPLAN has found no further word on this project; it would certainly be interesting to find out what became of it. Presumably anti-transit feeling in the LA area and lack of adequate funding were the prime reasons for its disappearance.

In Denver, the voters have approved funds for construction of a 100-mile PRT network which will reportedly have a link to the airport. This system may be the only example of an advanced system with an airport link which has reached the voters. In contrast, a PRT system recently proposed to connect the Las Vegas CBD and McCarran Airport, 24 miles away, failed to win support. The system would have run on an elevated guideway, using monorail or possibly magnetic-levitation technology and vehicles carrying one to six passengers. The system would have a capacity of 2,800 passengers/hour/lane (8-second headways), and was estimated to be capable of attracting 25 million revenue passengers per year. It has been estimated to cost $100 million, or about $4 million per lane mile (44). According to the September 15, 1974 Public Transit Report, however, two proposals for the system have been rejected by the county commissioners, who claimed that they felt the system was technically feasible but that indifference on the part of businessmen and the reluctance of citizens and the tourist industry to provide support forced them to abandon the project.

IMPACTS ON GOALS. The impact of improving transit access to airports would be that, to the degree that transit replaced private autos and taxis as a means of airport access, pollutant emissions and fuel consumption would be decreased, as in the case of other transit-oriented strategies and actions (1.2, 2.1.4). No estimates of these impacts were found, however, and in light of the fact that, as explained below, it will be very difficult to make transit available, much less attractive, to auto users for airport trips, it would seem that the impact on airport trips alone would be very little. The effect on total trips and congestion would be practically negligible, since airport travel now is only a very small portion of total urban travel, around 1 percent of daily VMT.

This does not mean that airport transit service is not needed. Many cities already have a transit link between the airport and the CBD. On the average, about 30 percent of resident and non-resident airport trips (less than 25 percent of air passengers) are moving to or from the CBD (229, p. 42), and non-resident travelers represent over 85 percent of these in most cities. Thus, though a majority of airport trips originate or terminate outside the CBD, the CBD is still the principal single generator of airport traffic in a metropolitan area and therefore should be served by a quick, efficient transit link to the airport, especially since a high proportion of CBD airport travelers are non-residents, many of whom do not have access to an owned or rented car.

However, very few urban *resident* trips to airports originate in the CBD, about 4.5 percent in Philadelphia (57) and even fewer in Los Angeles. Resident airport trips have very dispersed origins and destinations, as illustrated for Philadelphia in Figure 2-7. The widely dispersed pattern makes it very

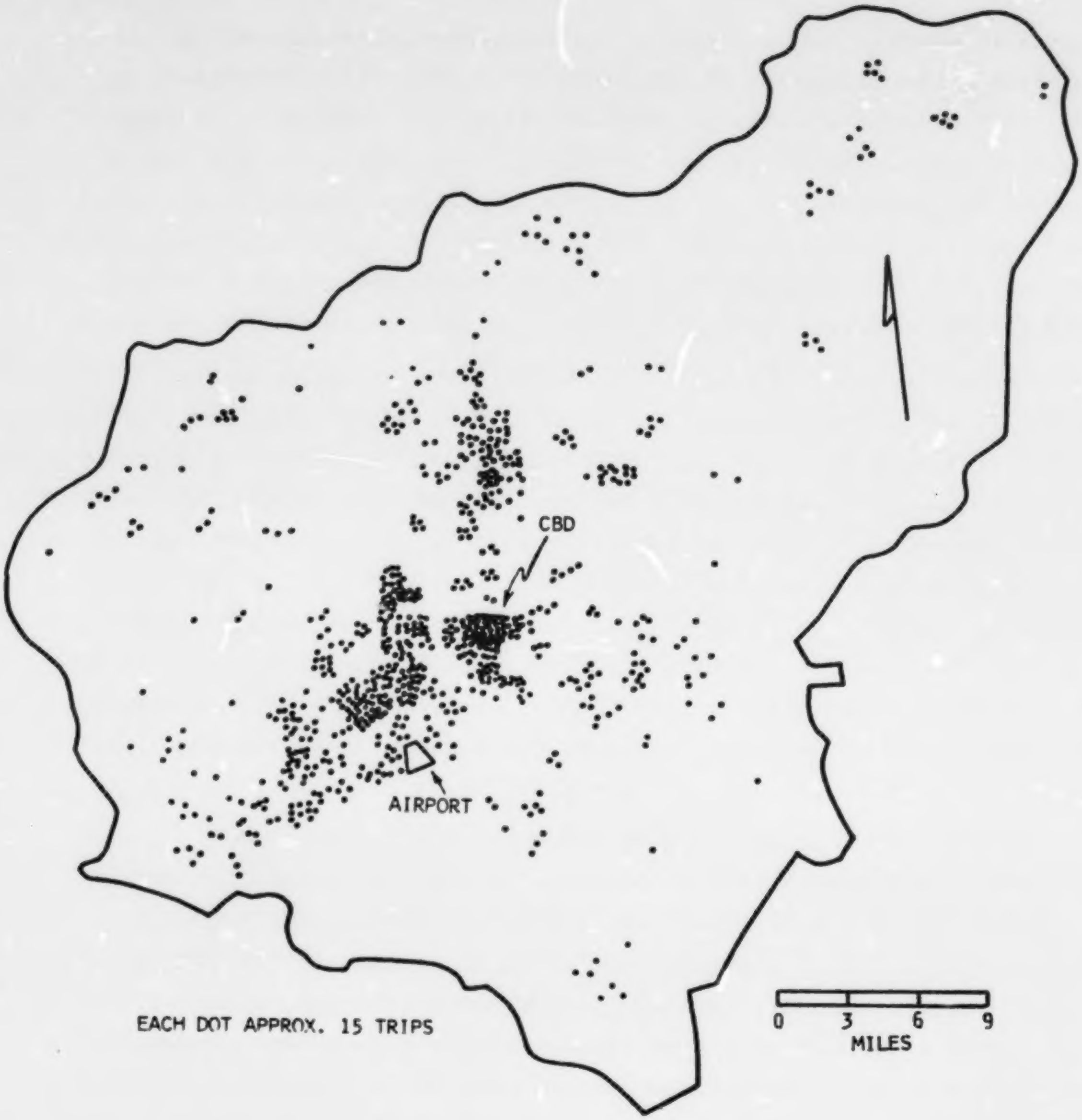

Figure 2-7. Geographical distribution of all resident airport trip origins, trips to Philadelphia International Airport.

Source: Reference 155, p. 28.

difficult for transit to provide adequate and economical airport access for airport travelers not traveling to and from the CBD.

In addition to resident and non-resident air passengers, airport travelers include airport employees, shippers, tourists, residents making recreational visits, and friends of passengers. In the top 20 U.S. airports, airport employees about equal the number of air passengers, and there are up to 1.5 visitors for each air traveler (229, p. 13). While air passengers make up 30 percent of all airport trips, visitors and greeters account for another 35 percent, and employees and all others, 35 percent (229, p. 11). There is no one solution to the problem of providing transit airport access for such a diverse group of travelers, unless the airport is close enough to high-density areas to be a logical node in an area-wide transit network. Transit links with the CBD will serve many air travelers but are unlikely to serve many airport employees, who often live near the airport but not necessarily on the CBD-airport corridor. For employee work trips, which are the most auto-oriented of all airport trips, some of the other strategies discussed in this study would be more directly applicable, such as car and subscription buspools (see Section 3, strategy 3.1).

Other drawbacks to proposed transit access improvements include the inconveniences of transit for travelers and their luggage, such as the need for transfers, the fact that some transit facilities are already overcrowded during rush hours, and the fact that few transit vehicles have adequate, if any, provisions for carrying or transferring baggage. Conventional transit systems such as bus, taxi or limousine, also suffer from the disadvantage of unreliability of service during periods of congestion, and are subject to traffic delays just as are private vehicles. On the other hand, transit modes which offer service on a separate right-of-way and thus avoid the problem of traffic delays (i.e., busways, subways, monorail, TACV) are very expensive to provide.

Transit does offer advantages to some airport tripmakers. It is probably cheaper in monetary terms than driving to the airport and paying to park there, and transit on an exclusive right-of-way can provide travelers with the assurance that they will not miss their flight because of traffic delays. But in general, it is felt that the large majority of airport patrons will continue to prefer the private auto as a means of airport access. The auto offers the convenience of using the same, driver-controlled vehicle from origin to destination, lower perceived cost (out-of-pocket plus intangibles), better provisions for baggage, and the fact that in most cases it is faster than or just as fast as transit.

Increase Short-Haul Intercity Rail Alternatives (2.3.2)

While providing transit access to airports may be a short- or medium-range action for alleviating airport access congestion, for the reasons given above, it will probably be difficult to attract any significant number of airport trips to transit. A long-term action, then, might be to improve the attractiveness of surface modes of travel so that they could compete with air travel for short-haul trips (up to 300 or 400 miles one way). Diverting some air passengers to the rail mode would logically decrease the number of people needing to make airport trips; they would go to the downtown train station instead.

EXPERIENCE. The intercity rail mode appears to be the most realistic alternative to air travel. INTERPLAN found no proposals for improved intercity bus service as a substitute for air travel; buses probably could not provide fast enough service to compete with air service on most trips. Moreover, since bus service quality in terms of passenger comfort is lower than that of air or rail, bus travel does not directly compete with these modes despite its time and price advantage over present U.S. rail service, and its price advantage over air travel.

While rail passenger service in the U.S. has declined drastically for many years, the formation of Amtrak in 1970 seems to have reversed this decline and attracted many new passengers. In calendar year 1974, Amtrak carried 18.5 million passengers, a 20 percent increase over calendar year 1973. Passenger miles increased 30 percent, from 3.2 billion in fiscal year 1973 to an estimated 4.2 billion in fiscal year 1974. While the volume of rail passenger travel does not nearly approach that of air passenger travel, the trend seems to indicate that passengers are attracted to rail when improved service is made available (44).

The attractiveness of good rail service is most evident on improved short-haul runs such as the all-electric Metroliner, which provides 15 round trips daily between New York and Washington, D.C. The Metroliner completes this trip of 227 miles in an average of 3 hours. It is a very fast, advanced train design, capable of 160 mph on ideal track, though because of deteriorated track conditions, it now averages 75 mph. Even so, it provides a convenient alternative to an air trip between New York and Washington for many passengers. A 1971 DOT review of federal transportation subsidy policy states that the Metroliner has "shown convincingly that a modern train with a reasonably fast schedule can get and hold public favor. ... Metroliner experience makes it clear that the public will use a rail system that provides travel times shorter than private automobiles and comparable, *on an origin-to-destination basis*, with existing airplane travel" (327, pp. 4-4 and 4-11, emphasis added).

Another advanced high-speed system currently in operation is the Turbotrain running between New York and Boston, and also in use in Canada between Montreal and Toronto. Experience with the Turbotrain has not been as successful as with the Metroliner. Because of track limitations, the train's running time is only slightly less than the conventional rail time of 4-1/2 hours. Also, poor ticket selling and station arrangements inhibit many people from using this service (327).

Providing faster, high-speed rail service is only part of the effort required to attract passengers. Extension of service to more cities, a continued determined effort to upgrade the overall level of service and reliability, a more vigorous marketing program, and further steps to integrate intercity rail with other modes are also important. The integration effort has already begun: in June 1974, Amtrak and Greyhound Lines signed a landmark agreement. The companies will now sell tickets for each other, and one ticket can be used on both bus and rail. They have agreed to promote the complementary use of bus and rail modes to make a complete trip without the necessity of using an automobile at one or both ends. This will enable Amtrak to ticket its passengers straight through to many major cities such as Cleveland, Toledo, and Mobile, Alabama, which are not now served by rail (195). If this intermodal cooperation effort proves successful, however, it may have a greater impact on long trips than on the short-haul intercity trips which we are interested in diverting from air.

In the future, many researchers foresee magnetic levitation vehicles and TACVs as providing attractive short-haul intercity service. Neither system has yet been satisfactorily proven as far as technological feasibility or construction costs are concerned, though the TACV has probably been more extensively developed and tested than has the concept of magnetic levitation. TACVs are believed to be a very good mode of passenger transport for trips of up to 300 miles, the minimum distance for economical operation of commercial aircraft (363). While the maximum speed obtainable with conventional trains on conventional tracks is something less than 150 mph at most, the TACV may be able to exceed 300 mph. The TACV guideway is estimated to be considerably less expensive than conventional rail tracks, which are the most expensive component of a rail system. Costs for the French Aerotrain were estimated in 1966 to be $300,000-400,000 per vehicle (self-propelled, 80-passenger) and $660,000 per mile for a double glideway on pylons, compared to $2.5 to $3.2 million per mile for conventional railroad track (363). However, conventional rail has the advantage that a wide network of conventional rail already exists, though it might be prohibitively expensive to bring it up to the standard necessary for high-speed performance, as in the case of the Metroliner and Turbotrain.

IMPACTS ON GOALS. The effect on air travel of any improvements in intercity rail systems would materialize only in the long run. No one, to INTERPLAN's knowledge, has yet estimated the potential diversion of intercity passengers from air to rail on a national level. Any serious effort to do this would require data on the percent of air travelers who make trips of 400 miles or less. INTERPLAN's search to date, which included contacting the industry association in Washington, D.C. (the Air Transport Association of America), failed to uncover even this basic information. Therefore, it is difficult to estimate how much impact shifting these travelers to other modes might have on total travel to airports.

It is suspected that the diversion, whatever level it reached, would have little effect on the total number of air passengers, and thus on the number of persons making trips to airports. At the most, it is felt that improved intercity rail service might somewhat slow down the annual growth rate of air travel. Certainly some portion of new rail trips would be induced rather than diverted demand, and trips might be diverted to rail not only from air modes but highway modes as well.

The energy use impact of shifting intercity travelers from air to rail could be calculated for an estimated air-rail shift by using the figures in Table 2-12, which compares the propulsive efficiency of various intercity modes. A similar exercise could be performed to estimate the vehicle pollutant emission tradeoffs; INTERPLAN did not locate any reliable emission comparisons for intercity modes, though these figures may well have been derived in some document not yet in our files.

Table 2-12. Propulsive efficiency of intercity passenger modes.

Mode	(1) Passenger miles/gal.	(2) Vehicle miles/gal.	(3) Gallons of fuel used/mile (inverse of Col. 2)
Large bus (40')	125	5.0	0.20
Pullman night train[1]	18	.16	6.0
Cross-country train[2]	80	.4	2.5
Fast-Train[3]	133	.7	1.5
Electric Metroliner[4]	50	.2	5.0
"Hovertrains" (80')	22	.5	2.0
Small jet plane (707)	21	.25	4.0
Large jet plane (747)	22	.11	9.0

Note: Figures are in terms of petroleum equivalent of electric power consumption.

[1] The old standard 10-sleeper, 1-diner, 1-baggage car, 2-diesel Pullman train.

[2] One 150-ton locomotive and 4 70-seat coaches, plus diner-lounge and baggage coach.

[3] Three-car, self-propelled, bi-directional double-deck unit with 117 seats, weighing 67 tons per car.

[4] Six 80-ton, 61-seat new PRR Metroliner cars.

Source: Reference 234, p. 258.

Overall Evaluation

From the overall perspective of urban transportation, air quality, and energy use concerns, improving airport access is a relatively unimportant strategy. In the first place, airport access represents a real problem only in a small number of cities (15 to 20). Within these cities, it is a very site-specific problem, depending on the location of the airport in relation to the CBD, the proportion of air travelers using the airport who are inter-airline transfers, and other factors. Most importantly, airport trips account for only about 1 percent of total VMT in an average urban area, even though airport trips may contribute heavily to local congestion at certain urban traffic peak hours and during air travel periods (holidays, school closings). It is understandable that airport access to the CBD ranked 29th out of 33 priorities for new transportation systems projects in a 1968 report (63) and that a 1970 study concluded: "In comparison to other needs for limited public funds, the importance of improving airport access for airline travelers has a comparatively low priority" (56, p. 4). Furthermore, a successful program to improve airport access would impact primarily on congestion, and would have little potential for reducing either air pollution or energy consumption.

Moreover, the outlook is not particularly bright at the moment for either of the proposed actions to improve airport access. Though providing better airport transit service, for example, might be successful in diverting some airport trips, especially airport-CBD trips, the cost of transit systems can make them hard to justify since the improvements would benefit a relatively small number of people. These improvements are apparently not popular with the public, as demonstrated by the voters' rejection of a bond issue to finance an airport busway in Kansas City and the abandonment in Las Vegas of a plan to build a PRT system to the airport.

In most cases, airport access could probably be improved more economically and efficiently by concentrating on more comprehensive urban transportation strategies than by designing and constructing new systems specifically to solve the airport problem. As one study notes, "...faster [airport] access is more likely to result from improvements in general traffic flow" (239, p. 140). Likewise, the peaking problems due to airport work trips could best be approached by encouraging the formation of car or subscription buspools.

REDUCE PEAK-HOUR TRAFFIC VOLUMES (2.4)

The urban traffic peaking phenomenon can be directly attributed to the clustering within the same 1- or 2-hour periods of opening and closing times of work and shopping places, and to the concentration of these places in business and shopping districts at some distance from most residential areas. In the U.S., traffic peaks occur twice a day; in some European and Mideast cities, they occur four times a day since lunch periods still allow a midday break at home. It is during these peak periods that most congestion occurs: unacceptable service levels occur on about 19 percent of all urban roadways (freeways and principal arterials) during peak hours (Table 9, Volume 4, p. 26). Figure 2 (p. 13) of Volume 4 of this study shows urban traffic distribution by hour of day with its characteristic morning and evening peaks. The figure indicates that during the 8th and 17th hours of the day (7-8 A.M. and 4-5 P.M.) the urban roadway must carry 9-10 percent of total daily traffic, compared to about 5 percent per hour carried during the interpeak period, and 2-4 percent per hour in the evening, night, and early morning hours.

Several ways of altering work schedules to spread these peaks and reduce the number of vehicles which must be accommodated on urban roadways at any given time have been in use in isolated cases since World War II, with a revival of interest during the last five years. These altered work schedules, tested or proposed, can be characterized as either staggered rearrangements of the standard 40-hour, 5-day work week (discussed under action 2.4.1, Reschedule Work Hours), or a shortened work week, in number of days if not in number of hours worked, which may also be staggered with respect to days and hours (discussed under 2.4.2, Shorten Work Week). While the former can reduce the peak volume of traffic, only the latter has the potential to reduce work trip VMT, since it eliminates work trips on the fifth day.

INTERPLAN recognizes these are not the only two actions which affect peak-hour traffic volumes. A recent unreleased National Cooperative Highway Research Program report on peak-period congestion* includes, among the approaches with potential for reducing congestion, measures covered under seven other INTERPLAN strategies: Increase Transit Capacity (1.1), Attract Transit Ridership (1.2), Increase Auto Occupancy (3.1), Increase Cost of Auto Use (3.2), Restrict Zonal Access (3.3), Encourage Communications Substitutes for Travel (4.1), and Encourage Decentralized Land-Use Patterns (4.2). But the strategy of rescheduling or shortening the work week deals more directly with an immediate cause of the peaking—time constraints on travel—and is better understood and easier to implement by far than actions to alter the other immediate cause—physical clustering of business places.

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*Roberta Remak and Sandra Rosenbloom, Peak Period Traffic Congestion (Interim Report), prepared for the Transportation Research Board (Santa Barbara, Calif. and Austin, Texas, December 1974).

Reschedule Work Hours (2.4.1)

The two main approaches to rescheduling work hours are to stagger them at 15- or 30-minute intervals without altering the fixed workday length, or to allow employees to stagger working hours as they wish within broad limits. The first is generally termed "staggered work hours", while the second is known as "flexitime", "gliding work hours", or *gleitzeit* in German-speaking countries.

EXPERIENCE. With the exception of staggered work hours schedules in effect for federal agencies in Washington, D.C., since 1940, and recent experiments in a few U.S. cities, most of the experience with these techniques has been in Europe or at the U.S. headquarters of European companies which practice them at home.* Most of the European experience is not very useful in predicting the impact on congestion, since the Swiss and German firms which first initiated rescheduled work hours did so to entice employees in a tight labor market and not to reduce congestion. The U.S. and London, England experiments have been oriented to reducing auto and transit congestion (although the attractions of gliding work hours have not gone unnoticed), but not enough data has been collected from these cases to permit firms or areas considering rescheduling to predict reliably the impact on congestion.

Looking first at staggered work hour programs, the one in Manhattan is probably the best known and best documented. It was conceived by the Port of New York Authority as a means of easing peak-period transit congestion, since in Manhattan 80 percent of employees reach their offices by subway. The Downtown-Lower Manhattan Association was also interested in the idea and was instrumental in coordinating the project. The project officially began in April

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*A summary of experience with staggered working hours can be found in INTERPLAN's report on reducing the need for travel (140, pp. 71-73, A-9 and A-10).

1971, with 50,000 employees participating. More than 90 percent of these (46,000 employees) were to begin work at 8:30 A.M. instead of 9 A.M., and the remaining 4,000 at 9:30 A.M. A year after the project was begun, there were 60,000 participants representing 70 public and private employers. The program was judged successful in easing peak-period transit congestion in the area, and the overall response to the program by the participants was highly favorable. The project is continuing today, with close to 300,000 employees now participating (99).

INTERPLAN is aware of six other large-scale applications of staggered work hours, in Washington, D.C., London, Philadelphia, St. Paul, Ottawa, and Seattle. In Washington, hours of individual federal agencies have been staggered over a 1-1/2 to 2-hour period since 1940 in order to minimize peaks. Reporting and quitting times within each geographic area are adjusted to meet street and transit capacities. The General Services Administration is responsible for overseeing this program, which now involves over 300,000 government employees. Unfortunately, GSA reportedly has no data to describe the effect this program has had on traffic flow, although it is safe to presume that it has had a beneficial effect. In London, England, a staggered work hours experiment initiated in 1959 involved private firms rather than government employees. The British Ministry of Transport persuaded 145 firms with 21,000 employees scattered over the London area (2 percent of total commuters) to stagger work hours by 15-minute intervals. No further information has been found, and it is suspected that the experiment was abandoned soon after its inception.

The Philadelphia, St. Paul, Ottawa, and Seattle experiences with staggered work hours plans are described in the above-cited NCHRP report on peak-hour congestion. In all cases, traffic peaks were flattened out as anticipated. Data on traffic flow collected in St. Paul indicated that traffic volumes in the area of the major industrial plant where employee hours were staggered increased only half as much as total daily traffic in the metro area (17 percent vs 35 percent).

Most experience with gliding work hours or flexitime, which permits employees to choose their starting and quitting times as long as they work the required number of hours, has been in Europe, particularly in Germany and

Switzerland where its use is widespread. At least three headquarters of European companies in this country also have flexible work hours (Lufthansa in East Meadow, N.Y., Nestle in White Plains, and Sandoz-Warner in East Hanover, N.J.). No information is available concerning the impact of this technique on traffic flows, since it has been implemented as a sort of fringe working benefit designed to improve productivity and worker morale and not as a traffic measure.

The existing experience with staggered and flexible work hours may not permit reliable prediction of the impacts on traffic flow of these techniques, but it does seem to indicate that the following conditions tend to favor obtaining a significant result (239, p. 50):

- There is a single large employer (e.g., federal government) or a strong merchants' association interested in sponsoring the program.
- The work rescheduling proposal applies to a specific section of the CBD or other large activity center, rather than to an entire city or region.
- Adequate care is taken to design an effectively tailored program. The planning process can be quite complex and must take into consideration the number of firms and employees involved, the spatial distribution of the origins and destinations of their work trips, the temporal spread introduced by the work scheduling changes, differences in morning and evening peak-period arrival and departure characteristics, and special factors peculiar to the participating organizations.
- Transit authorities are willing to cooperate by adjusting schedules to meet new demand patterns.
- Administrative offices predominate in the area chosen rather than stores or offices dependent on clients drawn from outside the district.
- The activities involved are amenable to staggered hours. Factory work, data-processing, and work with strong peaking characteristics, such as payroll processing and other accounting functions, seem to be well suited to special scheduling. Publishing and sales work, on the other hand, which require constant contact with other conventionally scheduled firms, seem less suited to adopting new schedules until they are adopted on an industrywide basis. Table 2-13 shows one report's evaluation of the applicability of staggered work hours to various economic activities.

IMPACTS ON GOALS. Table 2-14 summarizes the available information on the impacts of staggered work hours, which are discussed below.

Congestion. The Manhattan program of staggered work hours, the most ambitious one to date on which data is available, was designed to relieve congestion on transit facilities. Although the impact of this experiment on vehicular congestion in Manhattan has been negligible, surveys taken before and after

Table 2-13. Applicability of staggered work hours to basic economic activity groups.

Employment Classification	Schedule Freedom	Staggered Hours Potential
Federal Government	Free[1]	Good; many small agencies
State Government	Free	Good
Local Government	Free	Good
Trans-Comm-Util.	Fixed[2]	Poor; transportation (trade oriented)
Education	Fixed	Poor
Service	Free	Good; banks (trade oriented)
Retail	Flexible[3]	Fair; large firms only
Manufacturing	Free	Fair +
Wholesale	Flexible	Poor

Source: Adapted from Wilbur Smith and Associates, "Staggered Hours Plan, Atlanta Metropolitan Area," 1970, p. 31

[1] "Free" indicates organizations with considerable latitude to set work hour schedules. In theory, schedules could encompass any period in the day if it were not for employee preferences. Shifts of at least one to two hours appear possible.

[2] "Fixed" indicates organizations with no flexibility to change work patterns to any schedule other than existing ones.

[3] "Flexible" indicates organizations which could potentially alter work hour schedules, but only if related firms (i.e., firms in the industry, customers, suppliers, and so forth) do the same. Since such shifts from established economic relationships usually involve a great number of firms and business practices, the extent of schedule change acceptable to such organizations is probably one hour or less.

Source: Reproduced from Reference 133, p. 7-26.

Table 2-14. Documented impact of strategies and actions on offsetting phenomena: Reschedule Work Hours (2.4.1).

PHENOMENA						COST ESTIMATES	
1.0 Improved Auto Alternatives	2.0 Improved Vehicular Flow	3.0 Reduced Urban Auto Use	4.0 Reduced Urban Travel Demand	5.0 Reduced Vehicular Air Pollutant Emissions	6.0 Reduced Vehicular Petroleum Consumption	Highway, Auto	Rail, Bus & Para-Transit
Reference 239 If transit operations are not coordinated with staggered work hours, some transit riders may have to switch to autos because of inadequate transit service during their new commuting hours (p. 41). Reduced congestion as a result of staggered work hours might encourage some commuters to switch from transit to autos (p. 44). In Manhattan program, congestion was reduced in the PATH Terminal and in several affected subway stations by 9-14% (p. 45).	Staggered working hours could result in substantial reduction in peak rush hour volumes, with at least some decrease in commuting time (p. 53). Projections for staggered work hours in Atlanta, Ga. (11,000 participating): cordon volume reduced 17% in busiest half hour, and 12% in busiest hour (p. 50).	Not mentioned.	Not mentioned.	If peak hour traffic congestion is reduced as a result of staggered working hours, emissions from idling engines should be reduced (p. 44).	Not mentioned.	Very low implementation costs. The Downtown-Lower Manhattan Association spent $50,000 to implement their program (including data collection before and after) (p. 41).	Not able at present to predict the economic effects on transit—some transit systems fear increased costs as a result of adjustments for staggered hours; others report more efficient use of transit facilities (p.41).
Reference 133 Relief of congestion might encourage a shift from transit to auto for the work trip (p. 7-10).	No figures.	Not mentioned.	Not mentioned.	Any reduction in peak hour traffic will generally improve traffic flow, and hence result in reduced emissions, even though there is no decrease in VMT (p. 7-4).	Not mentioned.	Not mentioned.	Not mentioned.

project initiation show that it succeeded in easing transit congestion. On the lower Manhattan subway lines, 6 percent fewer passengers moved during the busiest 10-minute period, between 9 and 9:10 A.M. At the PATH Hudson Terminal, the passenger volume during the busiest evening period, 5-5:15 P.M., dropped from 7,500 to 6,500, while passenger volume between 4:30 and 4:45 P.M. rose from 3,100 to 4,600. Overall, about 2,000 passengers shifted from the 4:45-5:45 period to the previous 45-minute period, as illustrated by Figure 2-8 (99, pp. 96-97).

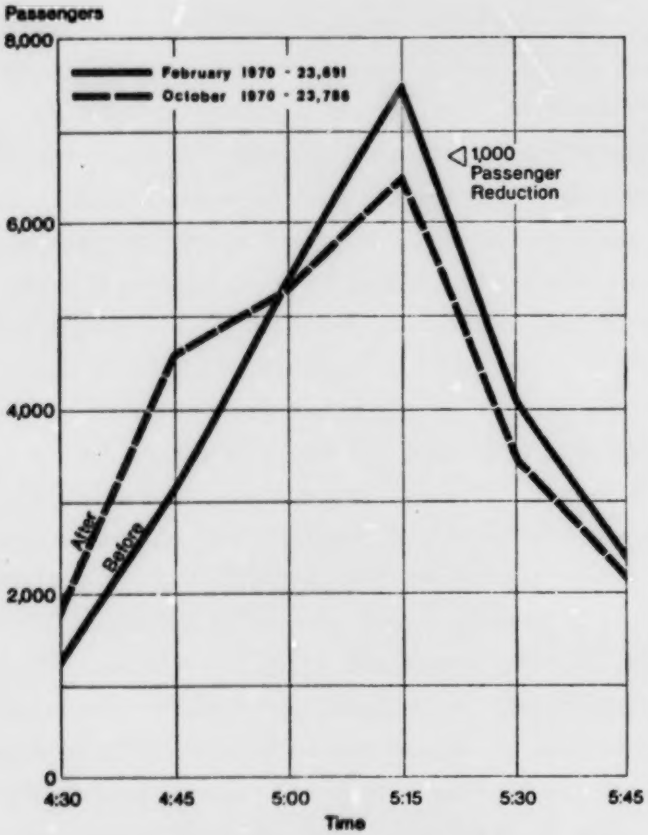

Figure 2-8. Effect of staggered work hours on evening passenger volumes at the PATH Hudson Terminal.

Source: Reference 99, p. 97.

The more recently initiated Philadelphia experiment, also directed primarily to relieving transit congestion, yielded even better results: the volume of transit (SEPTA) users during the heaviest 10-minute evening period decreased by about 20 percent, and transit travel in the periods preceding and following the original peaks increased. Since in Philadelphia the main issues so far have been whether staggering work hours relieves transit congestion and encourages transit ridership, and whether increased transit revenues can pay for required service expansion, there was no motivation there to collect data on the effects on auto travel.

In general, local agencies have not analyzed changes in traffic flow due to staggered work hours as thoroughly as transit flow was analyzed in the Manhattan experience because it was clear from observation and from routine data collection that the results were satisfactory. In St. Paul, for example, the Highway Department concluded from traffic counts in the vicinity of the plant where schedules were staggered that the traffic volumes in that vicinity had been reduced. They had no need to collect data on traffic flow by time period, which might have been useful to other analysts as an indication of the peak-flattening effect of staggering hours. Likewise, in Seattle the staggered work hours program is only one part of an effort by Seattle Metro to increase transit ridership. Transit ridership data are being analyzed, but no traffic studies are being made. The value of these experiences is, therefore, not that they form a basis for prediction of the impact of staggering work hours on the goals that interest us, but that they show that at least in individual cases the final results appear favorable. More specific conclusions would require a better analytical base. The comprehensive study now underway of the economic, traffic flow, and social effects of the Canadian federal government staggered-plus-flexible work hours plan in Ottawa should be a major contribution to this base. An examination of the 35-year history of federal government experience with staggering work hours in Washington, D.C. would also be useful, and could be used as the basis for a manual for implementing government staggered work hours on a large scale.

Even without a good empirical base, however, the evidence points to the effectiveness of a staggered hours program in spreading the traffic peak, particularly if implemented for a substantial portion of the work force in a well-defined part of a city. Projections for Atlanta, Georgia concluded that even a small-scale program involving 11,000 employees could reduce cordon traffic volumes by 17 percent in the busiest half-hour and 12 percent in the busiest hour (239, p. 50). Figure 2-9 illustrates the potential of the Atlanta program to even out peak-period traffic flows. No comparative actual data is available, however, since the rescheduling of work hours failed to win local support (140, p. A-9).

Two counterbalancing factors should be considered when assessing the potential congestion relief of staggered working hours. Firstly, a small increase in the number of single auto commuters may occur due to carpool disbanding and freer traffic flow. Staggering working hours reduces the number of people able to participate in carpools, and some existing carpools will be disbanded when members' hours no longer coincide. As part of the feasibility study of staggered work hours in Atlanta, a survey was made which showed that 27.2 percent of the employees were presently carpooling (239, p. 42) and that 58 percent of these would drive to work alone if their carpool had to be disbanded (133, p. 7-11). Also, if peak-hour congestion is significantly reduced by a program of work rescheduling, some commuters will probably be induced to shift from transit back to autos due to the lower congestion costs. Staggering work hours might therefore mean an increase in the number of persons driving to work alone rather than participating in carpools or using transit, and therefore an increase in VMT. While this increase may not seriously affect the overall benefits from the expected flattening out of peak-period travel, surveys such as the one made in Atlanta should be made to estimate the importance of this phenomenon in the individual case.

Secondly, if a staggered work hours program is initiated without careful coordination with local transit agencies, some employees who previously took transit to work may find that the transit service at their new hours is not adequate or convenient, and may thus be forced to drive to work. The cooperation of local transit agencies is, therefore, essential in insuring the success of such a program. Thus in Manhattan when the staggered hours plan was put into effect, operators adjusted transit service to meet new travel patterns: PATH added extra trains on its evening service from the Hudson Terminal

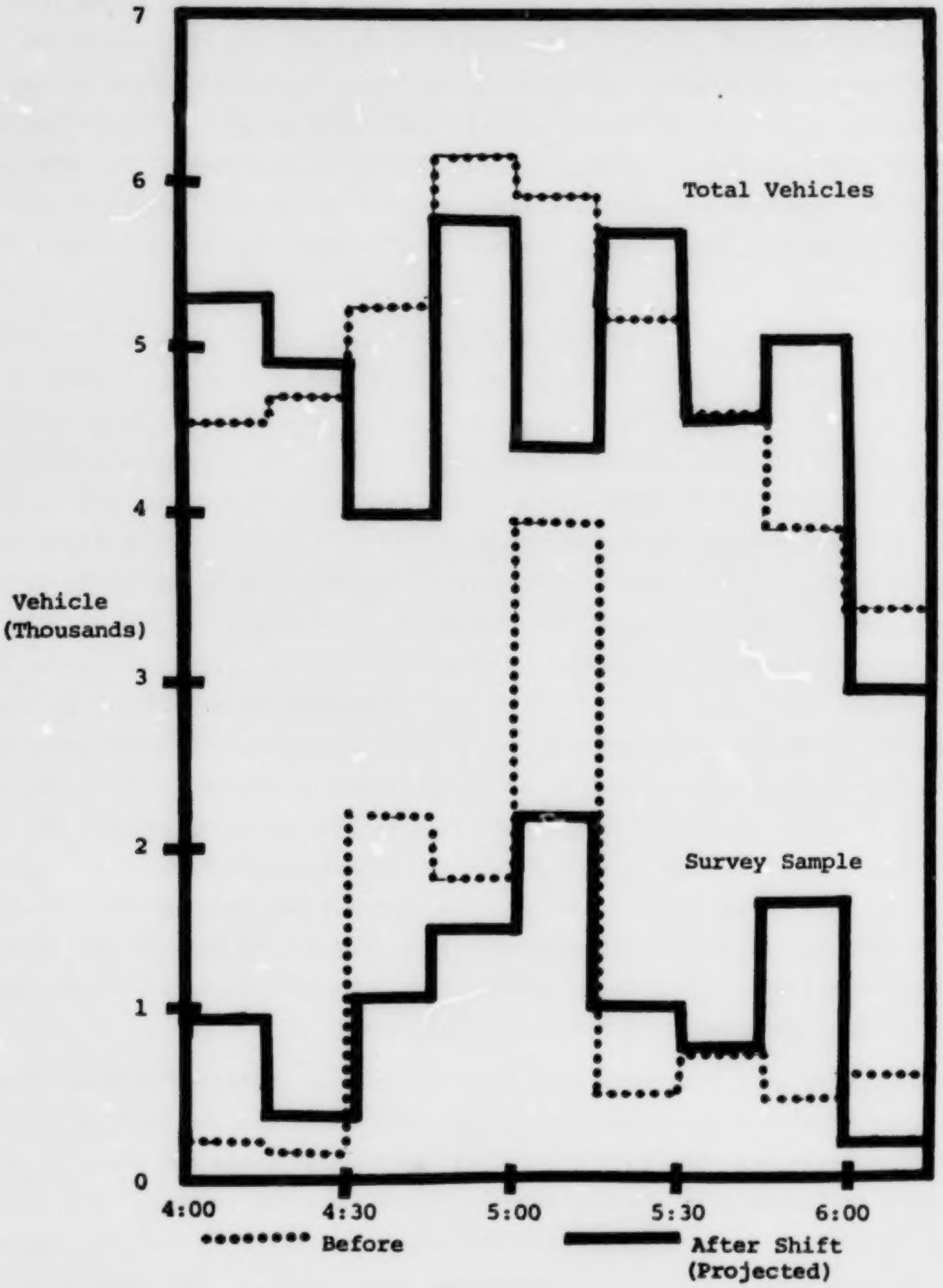

Figure 2-9. Projected effect of proposed staggered work hours plan on evening traffic volumes in Atlanta.

Source: Reference 239, p. 51.

to Newark; the New York City Transit Authority and Erie-Lackawanna increased service on routes serving the area; and Penn Central added cars on one of its trains (99, p. 99). These scheduling changes are reported to have cost $120,000. Fear of such additional costs may hinder transit cooperation in some cities. For example, transit authorities in Atlanta, Georgia "were not confident that they would be able to effect major schedule changes to accommodate work hour changes given the system-wide impact on bus operations" (239, p. 42). Lack of transit authority support is reportedly one of the reasons delaying implementation of staggered work hours in Atlanta.

On the other hand, some transit officials are pushing for changes in work scheduling because they believe staggered work hours would improve the efficiency and service quality of transit operations. In Ottawa, transit officials feel that if the peak period were expanded to two hours from the present 30 minutes, many buses which now make one peak-period trip and remain idle for the rest of the day would be able to make two or three peak-period trips (224). In Seattle, the transit agency estimates that if the current 8 A.M. travel peak could be redistributed over three periods peaking at 7, 8 and 9 A.M. the transit system could provide seats for 22,000 additional daily passengers, thereby relieving the heavy loads now carried on peak-period bus runs (227). Because buses during the 8-8:30 A.M. peak period are now running 20 percent above capacity, many riders are unable to find seats, and transit officials fear they may lose riders. Metro transit is planning to acquire new buses to increase transit capacity but feels that a staggered work hours program could relieve the problem until the new buses are delivered. Transit officials have proposed a plan which would involve 88,000 employees of seven private firms and several federal, state, city and county agencies (227).

Air Quality and Energy Consumption. Because staggering work hours does not reduce VMT, it has no direct impact on air quality and energy use. To the extent that traffic flow is improved, speeds increased, and idling reduced, some indirect improvement in energy use and reduction in CO and HC emissions will result. Moreover, because of the nature of the chemical reactions which occur in the formation of air pollution, air pollution may be diminished simply by changing the spatial and temporal distribution of pollutant emitters (cars), even though the total amount of pollutants emitted is not reduced. An air pollution problem is created when the local generation of pollutants exceeds the rate at which they are naturally dispersed and removed. Distributing traffic volumes over a longer period of time, as occurs when working hours are staggered, means that there will be greater air space available in which pollutants can disperse (7, p. 3-20). In this regard, it is more important to stagger the morning traffic flow than the afternoon one, because in the mornings wind speed is usually low, and the atmosphere is generally stable, conditions which inhibit the dispersion of pollutants. It is estimated that delaying the morning peak period in Los Angeles by one hour would reduce oxidant concentrations by 24 percent (7, p. 3-20).

Shorten Work Week (2.4.2)

The shortened work week takes two basic forms, the condensed 40-hour, 4-day week, which seems to be the most popular, and the reduced 4-day schedule, requiring less than 40 hours a week. Some businesses can adapt fairly easily to a 4-day work week, while others may find it difficult or almost impossible. As with staggered work hours, businesses which are primarily administrative have few problems in adopting such a schedule, while firms which must cater to customer hours or which are tied to delivery schedules, industrywide requirements, or home-office hours may not be able to adopt a 4-day work week. The difficulty of working in the dark morning and evening hours of a 10-hour winter work day may also be important to some activities, as in the case of the Los Angeles municipal parks and recreation department, which discontinued the 4-10 (4-day, 10-hours a day) schedule in 1974 after 15 months partly because of the difficulty of performing maintenance tasks during winter mornings and evenings ("City Agency Ends Disappointing 4-Day Work Week Experiment," Los Angeles Times, 16 September 1974).

Even with these limitations, the 4-day week is probably more widely applicable to the labor force as a whole than staggered work hours. The Southern California Association of Governments, for example, has estimated that 70 percent of the labor force in the South Coast Air Basin could be put on a 4-day work week (290, p. E-15). The one major constraint which applies to the 4-day, 40-hour week is labor union opposition to working days longer than 8 hours and to work weeks with non-consecutive days off (239, p. 50).

EXPERIENCE.* Estimates in 1972 of the number of firms on a 4-day week ranged from 600 to 4,000 (140, p. A-11). According to Reference 133, (p. 7-12), in 1972 less than 1 percent of the total U.S. labor force was on a 4-day work week. Despite this low level, the same source notes that an estimate that 1990 is the earliest time by which 35 percent of the labor force would be on a 4-day week may be "unduly low in light of the accelerating rate of conversion" of firms to the 4-day work week (133, p. 7-19). This suggests that the transition to a 4-day work week will occur more rapidly than the transition from a 6-day to a 5-day work week, which took about 20 years; the 5-day work week did not become the norm until 1940. Recent federal laws establishing standard Monday holidays have already, in effect, created five 4-day weeks for most employees every year.

IMPACTS ON GOALS. Table 2-15 summarizes the impact of this action on congestion, air quality, and energy consumption. These impacts are discussed below.

Congestion. While it seems obvious at first glance that a universal 4-day week should reduce work trips by 20 percent by eliminating work trips on the fifth day, the travel reduction on any given day will depend on how employees' working days are scheduled. Table 2-16 lists five alternative ways of arranging employees' 4-day work weeks; these are tantamount to staggering work days. As the table indicates, the individual arrangements have widely different results on daily traffic volumes. Table 2-17 interprets the figures from Table 2-16 in terms of the effect on freeway travel which alternative staggering of days would have if 35 percent of the work force were on a 4-day schedule. The table shows that the reduction in excess freeway demand over capacity from current conditions ranges from 33 to 99 percent. It is interesting to note that even on days when 100 percent of the 4-day employees are working there is a 33 percent decrease from current congestion. This occurs because the 35 percent of the labor force which is assumed to be on a 4-day week schedule begins work earlier and leaves later than the 65 percent of the labor force remaining on the 5-day week, which has the effect of staggering work hours. For this reason, mobility (i.e., decreased congestion) is better if 35 percent of employees are on a 4-day week than if 100 percent are (133, p. 7-18).

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*See Reference 140, pp. 71-72, A-11 and A-12, for a summary of experience with the 4-day work week.

Table 2-15. Documented impact of strategies and actions on offsetting phenomena: Shorten Work Week (2.4.2).

PHENOMENA						COST ESTIMATES	
1.0 Improved Auto Alternatives	2.0 Improved Vehicular Flow	3.0 Reduced Urban Auto Use	4.0 Reduced Urban Travel Demand	5.0 Reduced Vehicular Air Pollutant Emissions	6.0 Reduced Vehicular Petroleum Consumption	Highway, Auto	Rail, Bus & Para-Transit
Reference 239 Would reduce transit patronage by commuters who would only need to make 8 trips a week instead of 10 (p. 41).	No figures.	Traffic volume reduced from 8-34%, depending on portion of work force on 4-day schedule and number of employees working on a given day (p.52).	Could be reduced; see column 3.0.	Amount of air pollution caused by commuter trips should decrease (p. 44).	Not mentioned.	Not mentioned.	No figures.
Reference 133 Not mentioned.	Could reduce current congestion on Los Angeles' Hollywood Freeway from 33-99%, depending on how many 4-day employees are working on a given day (p. 7-14).	Maximum reduction in daily VMT is 2.5% (assuming: work trips account for 30% of VMT; 25% of the labor force is on the 4-day week; and working days are spread over 6 days) (p.7-20). Will probably not decrease total VMT, and may actually increase it. Decreased travel times are likely to encourage commuters to live further from work, especially if they only have to commute 4 days a week (p. 7-18).	Some persons may use the extra day off to obtain a part-time job; thus, work trips would probably not decrease by a full 20% (p.7-12).	If 2.5% reduction in daily VMT occurs, there should be a concomitant decrease in emissions. Emission reductions would probably also result from improved traffic flows (p. 7-20).	Not mentioned.	Not mentioned.	Not mentioned.

Table 2-16. Percent of employees working each day for alternative 4-day work schedules.

	4-Day Work Schedule	Percent of 4-Day Employees Working on a Given Day					
		M	Tu	W	Th	F	S
1.	Equally rotated M-F	80	80	80	80	80	-
2.	1/2 M-Th; 1/2 Tu-F	50	100	100	100	50	-
3.	Equally rotated M-Sa.	67	67	67	67	67	67
4.	1/3 M-Th; 1/3 Tu-F; 1/3 W-Sa	33	67	100	100	67	33
	1/2 M-Th; 1/2 W-Sa	50	50	100	100	50	50

Source: Vincent [illegible]. Desimone, "The 4 Day Work week and Transportation", A paper presented to the Joint ASCE ASME Transportation Engineering Meeting, Seattle, Washington; July 1971, p.9.

Source: Reproduced from Reference 133, p. 7-13.

Although the 4-day week is expected to reduce *work* trips and peak-period congestion, most sources believe it would not have a significant effect in reducing *total* daily VMT, and might actually increase it. Increased recreational travel on the extra day off each week and travel to work by persons using their days off to work a second part-time job could cancel out decreases in VMT due to reducing work trips by 20 percent. Decreased travel time as a result of the 4-day week might also influence some commuters to live even further from their jobs, especially since they would only need to commute four days a week instead of five (133, p. 7-18). Table 2-18 summarizes three estimates of percent VMT reduction resulting from 4-day work week applications. All three are less than 5 percent, much lower than the estimated reductions shown in Tables 2-16 and 2-17, which did not consider the impact of counterbalancing non-work trips.

Table 2-17. Daily impact of alternative 4-day work week arrangements on conditions at a freeway bottleneck.

4-day Work Week Arrangements[1]	Percent of 4-day Employees at Work Each Day[1]	Number of 15-minute Periods Demand Exceeds Capacity	Excess Demand Over Capacity (Vehicles)	Reduction from Current Conditions[2] (%)
2 or 3 days/week, half-and-half plans	100	8	1,181	33
Equally rotated M-F	80	3	577	69
Equally rotated M-S; 2 days/week, 1/3-1/3-1/3 plan	67	2	414	77
2 or 4 days/week, half-and-half plans	50	2	234	87
M,S: 1/3-1/3-1/3 plan	33	1	69	99

NOTE: Data assume 35% of the work force is on the 4-day work week. Based on traffic flows on the Los Angeles' Hollywood Freeway at Highland Avenue.

[1] From Table 2-16.

[2] Under the current 5-day work schedule, the number of 15-minute periods demand exceeds capacity is 12 and the number of vehicles excess demand over capacity is 1815 for a given day.

SOURCE for columns 2-5: Adapted from Vincent R. Desimone, "The 4-Day Work Week and Transportation," a paper presented to the Joint ASCE-ASME Transportation Engineering Meeting, Seattle, Washington; July 1971, p. 13.

Adapted from Reference 133, p. 7-14.

Table 2-18. Estimated average daily VMT reduction from switching to a 4-day work week.

Source	Assumptions				Average Daily VMT Reduction (percent)
	% of labor force on 4-day week	4-day week arrangement	% of daily VMT attributable to work trip	Difference between work day and day-off driving patterns	
290 pp. E-14, E-15 (Los Angeles)	70	Employees rotated equally over 6 days.[1]	Not given.	Substituting another average weekend day for the last weekday results in a 4.8% reduction in weekly VMT.	0.6
133 p. 7-20	25	Employees rotated equally over 6 days.	30	Not considered.	2.5
106 pp. 86-87 (Los Angeles)	80	Employees rotated equally over 6 days.	32	Personal travel on extra day off might be somewhat less than present average weekend travel.	4.0

[1] Cf. Alternative 3, Table 2-16.

Air Quality and Energy Consumption. The differences between the alternative 4-day work week arrangements in Table 2-16 become significant when discussing this action's potential for reducing pollutant emissions, because it is the daily, not the weekly, reduction in VMT that is important in reducing average 8-hour CO concentrations. Four-day work week arrangements that "...result in no reduction in the percentage of employees reporting for work on any [just one] weekday are less acceptable for air pollution control purposes (even if considerable reductions occur on all other days of the week) than equally rotated 4-day work schedules..." (133, p. 7-20). The optimum 4-day work week schedule from an emission control standpoint, therefore, is the one in which employees are equally rotated over six days (Monday to Saturday), resulting in a 33 percent daily reduction in work trips (133, p. 7-20).

Another study estimates that if all employment were to switch to a 4-day work week, a 3 percent reduction in overall emissions would result, assuming that a typical vehicle would continue to average 33.8 miles per day during the work week and 27.6 miles per day during the weekend, as at present (102, pp. 80-81). On the other hand, if it is optimistically assumed that miles driven on a 3-day weekend remained close to the miles now driven on an average 2-day weekend, a 15 percent emission reduction could result.

As far as the impact on energy consumption is concerned, it has been estimated that the 4-day work week could reduce regional energy consumption from 1 to 6 percent, depending on the percentage of the labor force involved (15 to 70 percent), assuming that no additional recreational travel took place as a result of increased leisure time (6, p. A-39). If there is an increase in total VMT as a result of the adoption of the 4-day work week, most of it would probably occur during off-peak hours and in less congested areas. "Thus, from the standpoint of air pollution control, the shift in time, place, and purpose of travel resulting from the 4-day work week appears beneficial, even if total travel increases somewhat" (133, p. 7-18).

Overall Evaluation

In reviewing the effectiveness of staggered work hours and the shortened work week, it is important to distinguish between work schedules which reduce *both* total VMT *and* peak traffic volumes, and those which affect only one of these objectives and not the other. Staggering work hours without shortening the work week will help reduce peaking without in the least affecting the number of weekly work trips. Shortening everyone's work week to four days without at the same time shortening the length of the work day may reduce the number of weekly work trips by 20 percent, but it will not affect peak traffic. The reason for this is that lengthening the work day to 10 hours effectively shortens the length of the morning and evening periods over which opening and closing times may be spread. Shortening work weeks for only a portion of the labor force would reduce both peak traffic volumes and number of work trips somewhat. Shortening everyone's work week to 32 hours, reducing the number of days worked to 4, and staggering work times over 4-hour periods at the beginning and end of the work day would also reduce both peaking and VMT, but as far as INTERPLAN has been able to determine, this drastic a change has been neither proposed nor tried by anyone, although it is similar to the shorter work week advocated by labor unions.

The most important observation, however, is that since peak-period congestion is the major transportation problem in many urban areas, any work schedule resulting in spreading of the travel peak would be beneficial, even if there were no reduction in VMT and consequently no direct reduction in vehicular air pollution and energy use. Indirectly, both pollutant emission and fuel consumption rates would be lowered to the extent that speed is increased and idling decreased during lower peak travel. Air pollution is also indirectly relieved by spreading out the period of peak vehicular emissions so that meteorological forces have more time to disperse them.

Further advantages of work rescheduling as a strategy are its low cost and external benefits. Most project costs are one-time charges for feasibility studies and setting up organizational procedures. The Downtown-Lower Manhattan Association spent only $50,000 to implement the Manhattan project, including surveys, information programs, and before-and-after data collection (239, p. 41). Costs to the transit system for service changes could be important in some cases, however. Where successful, both flexitime and the 4-day work week have substantially improved employee productivity (140, p. 72), an important external benefit.

The drawbacks of this strategy include labor union opposition to 10-hour work days, uncertainty concerning the actual (as opposed to the predicted) impact on congestion, and unknown social impacts. Labor union policy that work after 8 hours should be paid as overtime may discourage some employers from trying a 4-10 plan. Uncertainty about impact on congestion stems from the lack of empirical data and from the recognition that work staggering may not be as effective in relieving congestion in cities such as Los Angeles or San Francisco where the proportion of peak travel attributable to work trips is relatively low.

Last but not least, both staggering and shortening work hours could have a wide range of impacts on Americans' life style, the economy, and the structure of society which have not yet been determined. Since this subject is outside the range of this report, the reader is referred to a Labor Department study, Changing Schedules of Work: Patterns and Implications (101), for a discussion of some of these impacts.

SECTION 3

REDUCED URBAN AUTO USE (3.0)

INTRODUCTION

The subjects of Sections 1 and 2, improved alternatives to private auto travel (1.0) and improved vehicular flow (2.0), both take an affirmative approach to promoting the goal of urban mobility. But a recurring theme in our review of these two phenomena has been the necessity of accompanying affirmative measures with restrictive ones—joining the "stick" with the "carrot"—in order for the affirmative approaches to be fully effective. The strategies described in this section are chosen to serve the need for some direct limitations on auto use so that auto alternatives, when provided, do not stand idle, and so that measures to improve vehicle flow do not relieve congestion only to see new demand flow in to fill the newly created "breathing spaces".

But just as the impact of improving auto alternatives and vehicular flow is enhanced by measures to restrict auto use, these measures in turn can engender far greater response from the driving public if coupled with those offering an alternative to the auto or an incentive to reducing auto travel in the form of better driving conditions for those trips still made, than if they are implemented in isolation. Thus, while increasing vehicle occupancy through carpools and buspools (strategy 3.1) can stand on its own as a strategy, more carpools may be formed if preferential treatment is given through permission to use express busways or lanes; increasing the cost of auto use (strategy 3.2) will encourage more people to reduce auto travel if alternative, less expensive transportation is made available where appropriate; and restricting auto access (strategy 3.3) has a better chance of being implemented on a scale large enough to be effective if convenient public transportation routes are provided to prevent loss of mobility to those traveling to, from, and within the restricted area.

The auto restrictive strategies reviewed in this section, therefore, should be viewed as only half of an effective strategy package to improve urban mobility; the other half should be drawn from the strategies which improve auto alternatives and vehicular flow.

INCREASE AUTO OCCUPANCY (3.1)

Introduction

Increasing the number of persons moved per vehicle mile or vehicle trip is one approach to reducing urban VMT and consequently congestion, vehicle emissions and energy requirements. Standard transit vehicles (bus and rail) have the highest occupancy advantage over cars, with their capacities of 45 to 80 persons, and para-transit the next highest with occupancies ranging from 6 to 20, but gains in occupancy can also be realized by increasing the number of persons riding in private cars. While for all trips, auto occupancy as percent of capacity is about the same as for transit and para-transit vehicles, about 50 percent (comfortable car capacity = 4), occupancy is much lower for work trips. There is, therefore, a potential for increasing auto occupancy on these trips and for organizing other forms of work ride sharing with larger vehicles such as vans and buses.

In the following discussion, the experience and impact of encouraging carpooling (3.1.1) and van and buspools (3.1.2) are presented separately. The two actions are then evaluated together as a single strategy.

Encourage Carpooling (3.1.1)

EXPERIENCE.* The National Personal Transportation Survey conducted in 1969-70 provides detailed information on car occupancies in the U.S. (322). Table 3-1 summarizes this information by trip purpose. Auto occupancy is about 2 for all trip purposes, and as high as 3 for social and recreational trips, but is at its lowest for trips to and from work, at about 1.5. This report also found that about 75 percent of work trips were made by drivers alone, compared to about 50 percent for all trips.

A 1973 survey taken by the National Opinion Research Center showed that 18.5 percent of all auto commuters were participating in carpools. This is consistent with an estimate based on a 1973 DOT memo, which stated that nationally, 10 to 20 percent of all person trips to work are made in carpools (159). Assuming that 85 percent of commuters use autos, this implies that 12 to 24 percent of auto commuters are now in carpools. Surveys taken in Los

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*Except where otherwise indicated, this discussion is based on References 5 and 164.

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Table 3-1. Average auto occupancy for incorporated areas by trip purpose, 1969-1970.

	Average Occupancy	
	Occupants per trip	Passenger miles per vehicle mile
Earning a living	1.4	1.5
To and from work	*1.4*	*1.5*
Related business	*1.6*	*1.6*
Family business	1.9	2.2
Medical and dental	*2.0*	*2.1*
Shopping	*2.0*	*2.2*
Other	*1.9*	*2.2*
Educational, civic, religious	2.6	2.4
Social and recreational	2.5	2.9
Vacation	*	*
Visits to friends or relatives	*2.3*	*2.7*
Pleasure rides	*2.8*	*3.2*
Other	*2.6*	*3.0*
All purposes	1.9	2.2

*Data insufficient for analysis.

Source: Reference 322, p. 8.

Angeles show from 6 to 28 percent of commuters in carpools, with an average of 16 percent.

Carpooling to date has been done mainly on a voluntary, informal local level. One major carpooling project found that working through employers yields better results than appealing directly to commuters through the media (Portland Metro Carpool Project, "Progress Report," 31 March 1974). The majority of carpool programs have been organized by large employers, often in response to a specific problem such as lack of parking space. Larger employers (over 300 employees) are more likely to take advantage of government agency offers of carpool program assistance than small ones, it was found in Portland. The most frequently mentioned examples of private employers organizing carpools include

Burrough's "Operation Oxygen" in Los Angeles, the Hallmark Card Company in Kansas City, McDonnell Douglas in St. Louis, and several government agencies in Washington, D.C., especially NASA which has been running a carpool program since 1964. Table 3-2 lists a sample of 25 carpool programs underway in 1974 and their organizers.

In most cases, there has not been enough time or money to determine the effectiveness of carpool campaigns or to measure the decline in auto and transit use due to increased carpooling. INTERPLAN did find a few statistics, however: Burroughs claims that one-third of their employees volunteered for carpools in response to a company questionnaire. On the basis of a spot check in the parking lot on one day, there were 35 percent fewer cars after the program was initiated than before. McDonnell Douglas in St. Louis states that the average occupancy of cars entering company-owned lots has risen to 2.8, and NASA gives an occupancy rate of 3.85 persons per car.

There are some indications that larger, public organizations are beginning to get involved in carpooling efforts. The Washington, D.C. Council of Governments is working on an areawide carpooling program; in Dallas, the City Department of Traffic Control coordinates a carpool program; in Denver, carpooling is promoted by Downtown Denver, Inc. and the AAA club, while the computer matching programs are run by a local high school class; in Santa Barbara, INTERPLAN's home, the local newspaper and a radio station are setting up a citywide program; and in Knoxville, the transit authority has organized a carpool and buspool program.

Following the passage in 1974 of the Emergency Highway Energy Conservation Act, which authorized DOT to fund carpool demonstrations, existing carpooling projects have been able to expand with new federal funding in Portland, Eugene, Dallas, Ft. Worth, and Baton Rouge (William F. Ryan, "Carpooling, A Quick Fix for Mass Transportation," Mass Transit, July 1974, pp. 16-19). The availability of these funds should also stimulate new carpooling programs.

IMPACTS ON GOALS. Conflicting estimates have been made of the potential VMT reduction and energy savings from increased carpooling on the basis of a variety of assumptions about what kinds of gasoline savings are associated with higher work trip occupancies, and what is a "reasonable" carpooling occupancy target. Carpooling's effect on vehicle pollutant emissions is assumed to be

Table 3-2. A sample of 25 carpool programs and their organizers.

Coordinating Agency / Location	Private						Public							
	Chamber of Commerce	Business Firms	News Media (Radio, TV, etc.)	Auto Clubs (AAA, etc.)	Educational Institutions	Other	Transit Organizations	Council of Governments	City Planning or Traffic	County	Federal DOT	State DOT	Governor	Regional Transp. Planning Comm.
Atlanta, Georgia		x	P	P										
Austin, Texas									P					
Boston, Massachusetts			P	P										
California - Statewide												P	x	
Charlotte, North Carolina	P	x												
Chicago, Illinois		x	P											
Dallas, Texas		x							P					
Denver, Colorado		x(2)		x	P(1)	x								
Fort Worth, Texas	P	x	P											
Indiana - Statewide		P												P
Knoxville, Tennessee					P(3)		P(4)							
Michigan - Statewide												P		
New Orleans, Louisiana			P											
Northern Virginia			x											
Omaha, Nebraska	P	x					x							P
Philadelphia, Pennsylvania			P	P										
Pittsburgh, Pennsylvania			P											
Fort Huron, Michigan	P				P(5)									
Portland, Oregon		x												
San Fransisco Bay Area, California		x						P			P			
Santa Clara County, California										P				
Seattle, Washington									P	P				
St. Louis, Missouri			x					P						
Winston-Salem, North Carolina		x							P	P				
Wisconsin - Statewide			P									P		

P - Primary Coordinator
x - Provides Assistance
(1) - George Washington High School
(2) - Downtown Denver, Inc.
(3) - University of Tennessee
(4) - Knoxville Transit Authority
(5) - Community College

Source: Reference 5, "Organization for Carpooling," p. 3.

proportional to VMT reduction and has not received special analytical attention, to INTERPLAN's knowledge. Figure 3-1 shows DOT-TSC's estimation of gasoline savings as a function of auto occupancy (passenger miles per VMT). According to this figure, if PMT/VMT doubled from 1.6 to 3.2, a 9 percent savings in transportation fuel would be achieved, or about 10.5 billion gallons. But another DOT estimate cited in Mass Transit (Ryan, op. cit.) and Passenger Transport (18 January 1974, p. 1) claims twice these savings, or 20 billion gallons in annual gasoline savings, from the same increase in occupancy, and 5 billion gallons savings from increasing the ratio from 1.6 to 2.0.

These increases in work trip auto occupancy are probably overly optimistic. First of all, another DOT-TSC research paper (159) cautions that auto occupancy is likely to be an inflated measure of the level of organized carpooling, as this measure masks such phenomena as wives driving their husbands to kiss-and-ride lots. Furthermore, "average auto occupancy alone is an incomplete indicator of effectiveness of policies to curtail auto use. Variations in total numbers of autos as well as level of average multiple occupancy [number of persons riding in carpool vehicles] may significantly affect auto usage levels." However, most predictions of VMT reductions due to increased carpooling have been made on the basis of increases in average auto occupancy figures.

The same research paper notes that relatively large increases in the level of carpooling are required in order to achieve seemingly modest increases in average work trip occupancy, as shown in Table 3-3. For example, to raise average auto occupancy for work trips from 1.4 to, say, 1.8, which seems a modest enough increase, the proportion of individuals traveling in multiple-occupancy autos (2.5 persons per auto) would have to be increased by 50 percent, from 47.5 percent commuters in multiple-occpuancy cars to 73 percent. If this could be achieved, and assuming that an average multiple-occupancy figure of 2.5 is feasible, the DOT-TSC paper predicts a 35 percent reduction in auto work trip usage. If overall total auto occupancy for the work trip were raised to an average of 2.5, a maximum reduction of 48 percent in auto work trip usage is predicted. While these figures are certainly impressive, it seems both unlikely and impractical to aim to convert 73 percent of all commuters to carpool use.

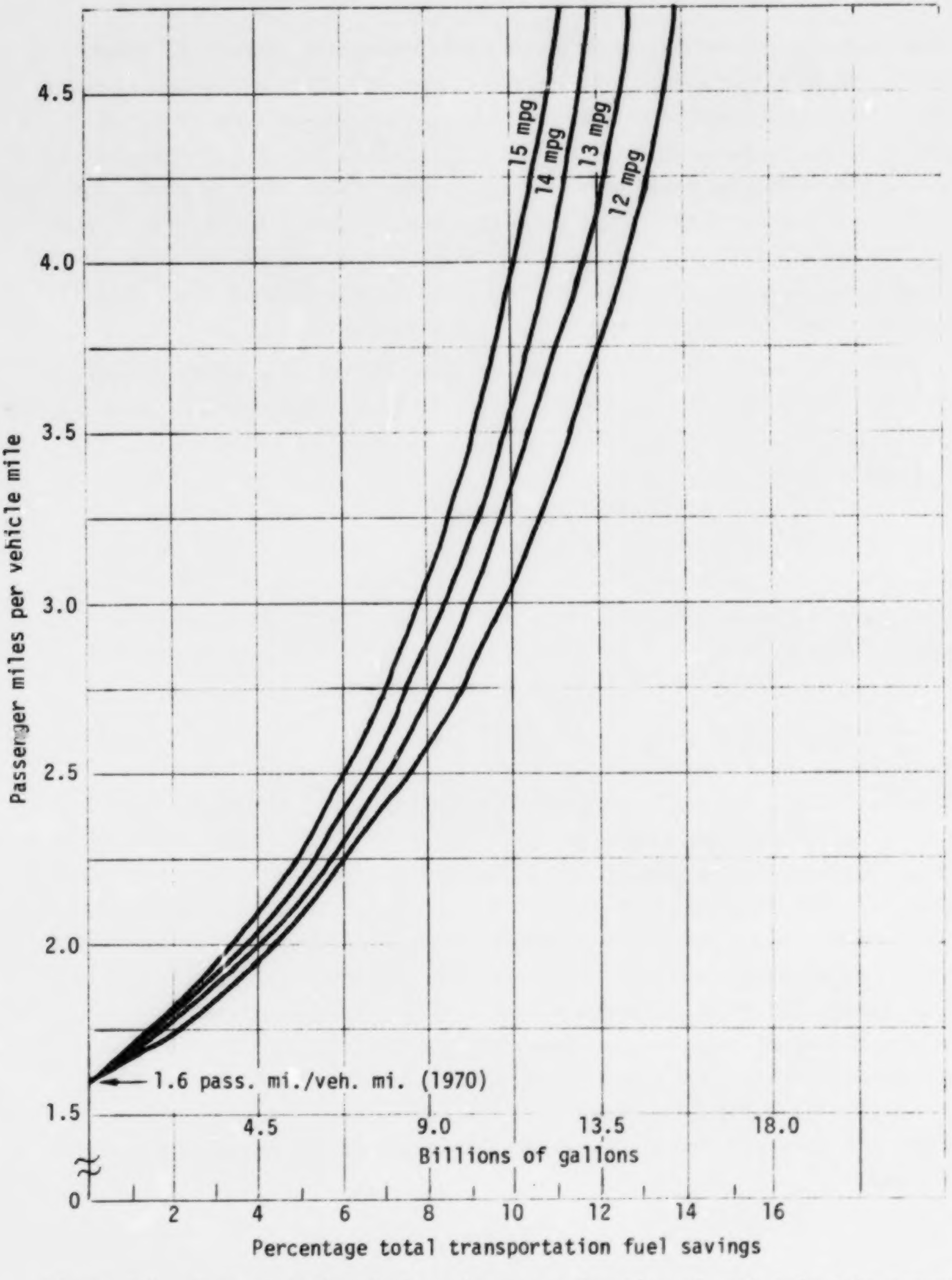

Figure 3-1. Transportation fuel savings as a function of work trip auto occupancy.

Source: Reference 254, p. 6-6.

Table 3-3. Relationship between average auto occupancy and percent autos with more than one occupant.

Work Trip Auto Occupancy		Percent Commuter Autos With More Than 1 Occupant	Percent Commuters In Autos With More Than 1 Occupant
Average for autos with more than 1 occupant	Average for all autos		
2.5	1.2	13.3	27.6
2.5	1.3	20.0	38.0
2.5	1.4	27.0	47.5
2.5	1.6	40.0	62.0
2.5	1.8	53.0	73.0

Source: Reference 159, p. 18.

For this reason, the figures arrived at in DOT-TSC's "Transportation Energy Conservation Options" (254) seem unrealistic. In this report, fuel savings (see Figure 3-1) are calculated under the assumptions that an occupancy of 2.0 PMT/VMT is a practical 5-year goal and that one of 2.65 PMT/VMT is a practical 15-year limit. But even a figure of 2.0 PMT/VMT assumes that 75 percent of all auto commuters are riding to work in carpools containing an average of 3 people, and implies a return to carpooling equivalent to that occurring in early wartime. During World War II, automobile occupancy for work trips rose from 2 (July 1942) to around 3 (March 1943) (5). It is felt these occupancies are not likely to be attained in the foreseeable future because the war crisis of the 1940s was perceived as much more threatening than the present "energy crisis", and because Americans today are probably much more habituated to and dependent on the independence and flexibility of private auto use than they were 30 years ago.

A more reasonable goal might be the one proposed for Los Angeles by the Local Agencies Task Force (LATF) and presented to EPA in September 1973 (180). The plan states that an attainable objective for the proposed regional carpooling system would be 50 percent of driving employees in carpools and an overall occupancy ratio of 1.5. This objective would yield a 25 percent reduction in home-work vehicle trips, or a 6 percent reduction in regional VMT, since work trips in Los Angeles account for only 25 percent of local VMT. The LATF carpooling occupancy objective is similar to the one proposed for Los Angeles in a scenario prepared by TRW Transportation and Environmental Operations for submission to EPA in the California state implementation plan (290) and to a later Southern California Association of Governments' (SCAG) scenario for a 20 percent VMT reduction in Los Angeles (267), although these three plans' estimates of the resulting VMT reduction are not consistent.

TRW (290) states that in Los Angeles auto occupancy for home-to-work trips is 1.1, and that more than 90 percent of auto work trips on the city's freeways are driver-only trips. If all freeway commuter travel were to be carried in carpools with an average occupancy of 3, and if no new VMT were to be generated from picking up and dropping off passengers, the maximum VMT reduction would be 17 percent. This figure reflects the fact that freeway commuter travel accounts for less than 25 percent of total daily VMT in Los Angeles. Since it is unrealistic to propose that all freeway commuter travel be carried in carpools, TRW settles on an achievable average auto occupancy for commuter trips on freeways of 1.5, which would result in approximately a 4.4 percent reduction in VMT.

The SCAG scenario (267) agrees with TRW that present commuter auto occupancy in Los Angeles is about 1.1 (1.14, to be exact), and also recommends increasing it to about the same level as TRW (1.39 vs TRW's 1.5). SCAG adds that this would require 1.3 million daily work vehicle trips to be diverted to carpools and an equal number to transit. Therefore on the basis of Table 3-3, the LATF-, TRW-, and SCAG-recommended commuter auto occupancy of 1.4 to 1.5 implies that 47 to 55 percent of all auto commuters would have to be carried in multiple occupancy vehicles (2.5 occupants), compared to the present level of 12 to 24 percent. This seems a much more realistic goal than the 75 percent recommended by DOT-TSC (254). However, the three Los Angeles plans do not agree on the resulting VMT reduction from this increase in work trip occupancy: LATF estimates a 6 percent, TRW a 4.4 percent, and SCAG a 15 percent reduction in VMT.

Conclusions regarding the impacts of carpooling are summarized in Table 3-4.

Initiate Van and Buspools (3.1.2)

EXPERIENCE.* The advantages of carpooling are that it makes use of existing spare auto passenger capacity, offers a service tailored to meet the door-to-

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*Except where otherwise indicated, this discussion is based on References 5, 162 and 164.

Table 3-4. Documented impact of strategies and actions on offsetting phenomena: Encourage Carpooling (3.1.1).

PHENOMENA						COST ESTIMATES	
1.0 Improved Auto Alternatives	2.0 Improved Vehicular Flow	3.0 Reduced Urban Auto Use	4.0 Reduced Urban Travel Demand	5.0 Reduced Vehicular Air Pollutant Emissions	6.0 Reduced Vehicular Petroleum Consumption	Highway, Auto	Rail, Bus & Para-Transit
Reference 254 Not mentioned.	Not mentioned.	May ultimately make lone driving more attractive because of reduced congestion and parking problems (p. 6-11).	Not mentioned.	Relief from air pollution in direct proportion to reduced VMT (p. 6-1).	For a car averaging 15 mpg, raising passenger miles per vehicle mile from 1970 level of 1.6 to 2.0, as a result of moving 3/4 of all auto commuters into carpools of 3 persons, would save close to 4 billion gals., which is about 3.5% of total transportation fuel usage. At a level of 2.5 pass. mi./vehicle mi., savings would be 6 billion gals.—6% of transportation energy use (p.6-6).	Reduce average out-of-pocket costs $100-225/year (15-35% of cost of operating a standard auto 10,000 miles/year). May also reduce need for multi-car ownership (p. 6-1).	Not mentioned.
Reference 239 May affect transit ridership. The percentage of potential carpool members who are current bus riders should be determined.	Decrease in congestion would depend on the proportion of current bus riders attracted to carpools (p. 95).	With widespread implementation of carpools, dramatic reductions of vehicle volumes are possible. If only 10% of peak period users of a congested corridor would switch to carpools averaging 4 people, a 7-1/2% reduction in vehicles would result (p. 92).	Not mentioned.	No figures.	Not mentioned.	Carpool with 4 members saves the user 75% of normal automobile commuting expenses (p. 87).	Not mentioned.

Table 3-4. (continued)

PHENOMENA						COST ESTIMATES	
1.0 Improved Auto Alternatives	2.0 Improved Vehicular Flow	3.0 Reduced Urban Auto Use	4.0 Reduced Urban Travel Demand	5.0 Reduced Vehicular Air Pollutant Emissions	6.0 Reduced Vehicular Petroleum Consumption	Highway, Auto	Rail, Bus & Para-Transit
Reference 159							
Not mentioned.	Not mentioned.	If average auto occupancy for urban work trips could be raised from present 1.2 to 1.8, 35% reduction in work trip auto usage would result. If occupancy rose to 2.5 there could be a 48% reduction (p. 19). Both are considered probably unattainable.	Not mentioned.	Not mentioned.	Not mentioned.	Not mentioned.	Not mentioned.
Reference 290							
Not mentioned.	Not mentioned.	Increasing auto occupancy for commuter trips on freeways in Los Angeles from the present 1.1 to an average of 1.5 would result in approximately 4.4% VMT reduction (p. 170).	Not mentioned.	Not mentioned.	Not mentioned.	Not mentioned.	Not mentioned.

door, direct (no-transfer) transportation needs of commuters, and can be organized and operated with a minimum of formality. Its limitations are the small capacity of the average private auto, and the average American's aversion to forced intimacy with persons of a different race, sex, social class, or smoking habits. These limitations do not apply to the two other forms of shared rides: vanpools, which use para-transit-type vehicles to pick up employees in the same residential area or along the same ride path and deliver them to the same workplace or workplace area, and buspools, which use larger vehicles to provide the same service. One vanpool could carry the same number of passengers as 5 or 10 carpools, and one buspool as many as 20 carpool equivalents. The larger vehicles generally allow more space per passenger than a car, and the impression of forced intimacy seems to be overcome in larger groups of riders which include a greater variety of people, and the potential for social interaction is seen as a plus. In the case of one vanpool program, riders felt that it made commuting "fun".

Although one might expect vanpools to be more widespread than buspools, since they can serve less dense demand concentrations and use vehicles which are easily obtainable rather than standard buses, which are currently in short supply, INTERPLAN found little evidence of vanpool experience. Only three examples were identified: B & B Minibus, which provides service to 300 black trainees who work at a Grumman Aircraft plant on Long Island through a grant from the Department of Labor; Monarch Associates, a private company which operated in New York City but is now defunct; and the program organized by the 3M Corporation in St. Paul, Minnesota. The 3M program, with a fleet of 40 vans and a waiting list of 600 employees, is quite successful. Its success is considered especially significant because the 3M Center is located in a suburban area which experiences relatively light traffic.

Current experience with buspools, on the other hand, is considerable. Table 3-5 describes the operations, markets served, and costs of 12 major buspools. As the table shows, there is a wide variety of operations, and the number of buspools seems to be rapidly expanding. The Reston Commuter Bus group is probably the most well-known and often cited (see column 1, Table 3-5). It is typical of many other buspool operations in that it was organized by an informal citizens' group which makes all decisions on changes or additions to

Table 3-5. Characteristics of 12 major buspools now in operation.

	Reston Commuter Bus, Inc.	So.Cal.Commuter Bus Serv.,Inc. (Com-Bus)	Colonial Transit, Inc.	National Geographic Society
GENERAL				
Location of Managing Organization	Reston, VA	Long Beach, CA	Fredericksburg, VA	Gaithersburg, MD
Type of Organization	Volunteer, non-profit	Private corporation	Privately owned and operated bus company	Large employer
Service began	1968	1967	Around 1967	1968
OPERATIONS				
Route Origins	Reston, VA	Orange County; San Fernando Valley	Virginia suburbs	Washington, D.C.; 2 Virginia cities
Route Destinations	D.C., Rosslyn, Pentagon	L.A. airport area	Washington, D.C., Pentagon	Gaithersburg, MD
Access at origin	Within a block	K&R	N/A	Walk or P&R
Route lengths (mi)	20-22	20-65; 30 average	20-50	About 25
Number of runs	25 both ways daily; 3 routes	47; 2 routes	33 runs daily; 16 to Pentagon	11 per day
Type of vehicles	Modern, air-conditioned transit buses	Late model, air-conditioned, suburban buses	Intercity coaches	Air-conditioned; reclining seats
Vehicle capacity	51	N/A	39-45	38-41
Occupancy factors	60% and higher	N/A	High—some standees	High—usually above 60%
Vehicles obtained from	W.M.A.T.A.	Charter bus companies; also owns 6 buses	Owned by company	Atwood Goldline Service (charter bus co.) and 2 other bus lines
Bus use during day	Deadhead; 1/2 used for off-peak serv.	Can be used by charter company	Parked at Pentagon	Deadhead to terminal
Drivers	Transit union members	Professional drivers; can take buses home	For Pentagon service—most are Pentagon employees	Professional full-time drivers
Special services	Busmeisters; 7:00 p.m. "straggler bus"	N/A	Conductors collect fares and monitor service	N/A
MARKET				
No. of subscribers	Approximately 800	N/A	N/A	540-580 [1973 data]
Type of riders	White collar, gov't workers; average household income $24,800	N/A	Military and civilian employees; all salary levels	Low to middle income N.G. employees
Percent of market	17	N/A	N/A	N/A
Competitive modes	Auto	N/A	N/A	Auto
Shift from other modes	Auto	N/A	N/A	N/A
COSTS				
Fares	$14/week	$10/week average	$8-11/week—Pentagon service	Approx. $5/week; N.G. contributes $7.50/week/rider
Costs	5¢/productive seat mile	N/A; self-supporting	N/A; self-supporting	3¢-4¢/productive seat mile

N/A = not available

Table 3-5. (continued)

	Specialty Transit, Inc.	Columbia Association	S.T.A.T.A.R.	Wayward Bus
GENERAL				
Location of Managing Organization	Wentzville, MO	Columbia, MD	Rochester, N.Y.	San Francisco, CA
Type of Organization	Privately owned and operated company	Small private group; also runs buses within Columbia	Small, non-profit informal group	Commuter groups
Service began	Late 1950s	1970	1965	Around 1960
OPERATIONS				
Route Origins	Rural areas around St. Louis	Columbia, MD (new town)	Downtown and suburban Rochester	San Francisco and Berkeley
Route Destinations	McDonnell-Douglas Corp., St. Louis	Washington, D.C.; Baltimore; N.I.H.	Kodak Park	Palo Alto-Sunnyvale area
Access at origin	K&R; P&R - Owner negotiates for free parking	N/A	P&R	N/A
Route lengths (mi)	9-52	About 30	20-25	35-50
Number of runs	24	13	1	2
Type of vehicles	Used school buses, modified for more leg room	Charter buses	Transit buses	N/A
Vehicle capacity	32-45	39-49	45-53	40-50
Occupancy factors	75%	N/A	N/A	N/A
Vehicles obtained from	N/A	Eyre's Bus Service Woodburn, MD and Carter Bus Service	Public transit authority	2 bus companies; utilizes buses on backhaul
Bus use during day	Parked at destination	All except one parked in suburban D.C.; drivers use other bus to go back and forth	N/A	Used by bus companies
Drivers	McDonnell-Douglas workers, employed as part-time drivers	Full-time, professional	N/A	N/A
Special services	N/A	Bus captains on each bus	N/A	N/A
MARKET				
No. of subscribers	650-800 [1973 data]	N/A	N/A	N/A
Type of riders	Blue collar workers	Mostly white collar, gov't workers	N/A	N/A
Percent of market	Owner estimates 90% at end points; 50% at intermediate points	N/A	N/A	N/A
Competitive modes	Auto, transit	N/A	N/A	Auto, regular transit, Greyhound
Shift from other modes	Auto, carpools	N/A	N/A	N/A
COSTS				
Fares	From $4 to $7.50/week	$10-15/week	$8/week; less if paid annually	Around $8-11/week
Costs	Little more than 1¢/productive seat mile	N/A; self-supporting	N/A	1.2-2.1¢ per productive seat-mile

Table 3-5. (continued)

	Golden Gate Bridge Highway & Transportation Dist.	Port Authority of Allegheny Co.	So. California Rapid Transit Dist.	Omaha Transit
GENERAL				
Location of Managing Organization	San Francisco, CA	Pittsburgh, PA	Los Angeles, CA	Omaha, NB
Type of Organization	Transit agency encouraging commuter clubs	Public agency working with bus clubs	Public transit agency	Public transit agency
Service began	1971	1950	1973(?)	Late 1973
OPERATIONS				
Route Origins	Marin and Sonoma Counties	Suburbs	Suburban locations	Suburban areas
Route Destinations	Downtown San Francisco	Downtown Pittsburgh	L.A. Financial Center	Downtown Omaha
Access at origin	Walk (1 or 2 blocks)	N/A	N/A	P&R
Route lengths (mi)	20-55	N/A	N/A; wide variation	12-18
Number of runs	11 (5 commute clubs)	5	10	3
Type of vehicles	Air-conditioned; not more than 12 years old	N/A	Air-conditioned transit buses	Transit buses
Vehicle capacity	Around 43	N/A	N/A	N/A
Occupancy factors	65%	N/A	96% of seats committed	"Satisfactory"
Vehicles obtained from	Charter and sightseeing bus companies	Owned by Port Authority	Owned by S.C.R.T.D.	Owned by transit agency
Bus use during day	Can be used by bus companies	N/A	N/A	N/A
Drivers	Full-time professional	N/A	Full-time professional	Union drivers
Special services	N/A	N/A	Bus hosts	N/A
MARKET				
No. of subscribers	470	N/A	432	N/A
Type of riders	White collar; middle and upper income brackets	N/A	N/A	N/A
Percent of market	N/A	N/A	N/A	N/A
Competitive modes	Auto	N/A	N/A	N/A
Shift from other modes	N/A	N/A	N/A	N/A
COSTS				
Fares	Around $6.50-11/week	N/A	Around $8-13/week	About $3.50/week
Costs	2.1-4.0¢ per seat-mile; GGBHTD subsidizes on the average $350/bus/month	N/A	N/A	N/A

Sources: References 162, 164, 269

routes and schedules and which leases the buses and drivers from a local transit authority.

Other private groups, for example, Com Bus in Los Angeles, lease buses from charter or sightseeing bus companies which charge less than transit operators because charter companies can make better off-peak use of vehicles and drivers and because their driver wage scales are not usually as high as those of unionized transit drivers. Subscription buspool services are also offered by privately owned and operated companies which are run as profit-making enterprises (Specialty Transit in St. Louis), commuter groups working through local transit agencies who in turn charter buses from outside firms (Golden Gate BH&T District in San Francisco), and transit companies who offer subscription buses as a part of their regular operation (SCRTD in Los Angeles and Omaha Transit). The latter practice seems to have great potential for application on a wider scale. The Los Angeles SCRTD experience has been very successful; available space has been 95 percent committed since the program's fourth month (November 1973) and advance pass sales doubled in the first 5 months (269).

Of the 16 buspools for which INTERPLAN found information, only two had failed. These two, the Flint, Michigan, Maxicab and the Peoria, Illinois, Premium Special, were initiated by UMTA and subsequently taken over by local transit authorities. In Peoria, the system was run as an UMTA demonstration project under the administration of the University of Illinois for the first two years. When the city transit company took over, routes and services were cut back and fares were raised 20 percent. Within six months ridership had declined 21 percent, and the project was ultimately discontinued. This experience illustrates the danger of approaching a buspool operation from the traditional transit viewpoint, and the need for innovative management thinking on the part of transit operators offering buspool service.

Service factors play a major role in assuring the success of buspools. Reliability is highly stressed in most operations and can be guaranteed by designated back-up drivers and ready availability of back-up buses in case of breakdowns. Another factor which can hardly be overemphasized is operational flexibility. Routes and schedules must continually be refined and adjusted and must be sensitive to changing passenger demands. The Reston Commuter Bus operation is a good example of service which has been responsive to the needs of its subscribers and has not been afraid to experiment with innovations considered inefficient by conventional transit standards, e.g., their introduction of a late "straggler" bus whose revenues do not cover costs but which has attracted 80 more subscribers to the program.

Subscription buses generally provide higher levels of service than traditional transit. Buses are often air-conditioned, a seat is usually guaranteed, and sometimes extra amenities are provided such as hostesses or bar stops on Friday evenings. Many buspool operations designate one person on each bus trip whose duties may include making sure that the driver follows the correct route, collecting fares, handling any problems that may arise en route, and handling complaints from passengers. On the Reston buses, these persons are referred to as "busmeisters"; Colonial Transit has "conductors"; Columbia, Maryland, "bus captains", and the Los Angeles SCRTD uses the term "bus hosts".

For most buspool riders, cost of the service is not the most important reason for their participation, though costs are usually competitive to those of auto commuting. When the Peoria Premium Special was in operation, a survey of riders showed that 71 percent felt convenience, reliability and short trip times were the most important factors in their joining the buspool, and only 7 percent cited cost as the most important. When Reston bus passengers were asked to rank the four most important measures for increasing ridership, they responded as follows: (1) reduce travel time, (2) lower fares, (3) provide more service, and (4) provide bus shelters.

Characteristics which favor subscription bus operations include:

- Medium to long commute distances. Services which pay their way generally have trip lengths of 10 to 50 miles; trips below 15-20 minutes travel time are better served by cars.
- High density destinations.
- High volume collection points (no more than 5 or 6 pickup stops).

Buspools function best in employment centers where large numbers of people have the same work schedules, such as large manufacturing plants or government offices. For this reason, staggered or flexible working hours on a large scale would be detrimental to buspools.

It is difficult to cite average operating costs for buspools. Operations differ widely in level of service provided, fares charged, miles traveled, use of full or part-time drivers, leased or privately-owned vehicles, and other characteristics. The Urban Institute estimates the cost per productive seat-mile to range from 1.0¢ to 4.5¢ (162). They also note that fare levels are generally set so the bus will break even at 70 percent occupancy. It appears that most buspools now in existence pay for themselves from farebox revenues, though the Golden Gate Commuter Clubs are subsidized by the Golden Gate BH&T District at an average cost of $350 per month. As mentioned above, some buspools are operated by private companies as profit-making operations.

IMPACTS ON GOALS. As Table 3-6 shows, impacts are expected to be positive but no quantitative estimates have been made. In general, the impact that buspools will have on reducing congestion, air pollution and fuel consumption is felt to be limited by the types of commuter trips for which they are suitable and by three other specific factors:

1. Whether or not there are local buses available for leasing. This may be a serious problem in some areas, especially as demand for buses by city transit agencies is currently exceeding supply. WMATA in Washington, D.C., has already refused to provide more buses for the Reston group, for example, though their policy may be based on other factors besides bus availability.
2. The degree to which buspools attract riders from more polluting, less energy efficient modes.
3. The degree to which bus pollutants and energy use generated by deadheading offset the gains generated by the switch from less polluting modes.

As the Vorhees' buspools volume (5) notes, "the energy efficiency of a buspool is dependent upon the use of the vehicle after the pooled trip has taken place." If the bus is used for a one-way commuter trip and then driven back empty, car or vanpools, which use vehicles which can be parked all day at the destination, might be more efficient. The amount of deadheading varies considerably with the mode of operation. A Reston transit-leased bus travels 58 miles for each 22-mile commute, it has been estimated. The Columbia, Maryland, operation, however, parks buses in a lot near its destination during the day except for one bus which the bus drivers use to go back and forth from the bus company headquarters. The Specialty Transit Company in St. Louis hires one rider on each bus as a part-time driver, and the buses are parked at their destination during the day.

Table 3-6. Documented impact of strategies and actions on offsetting phenomena: Initiate Van and Buspools (3.1.2).

PHENOMENA						COST ESTIMATES	
1.0 Improved Auto Alternatives	2.0 Improved Vehicular Flow	3.0 Reduced Urban Auto Use	4.0 Reduced Urban Travel Demand	5.0 Reduced Vehicular Air Pollutant Emissions	6.0 Reduced Vehicular Petroleum Consumption	Highway, Auto	Rail, Bus & Para-Transit
Reference 162 Not mentioned.	Contributes less to congestion than private cars or carpooling (p. 22).	No figures.	In the long run, high quality bus services may encourage commuters to live further from work (increased suburbanization). Results of Reston bus passenger survey showed 44% would not have moved to Reston if the service were not available.	Less pollution per passenger trip mile than private autos or carpools, depending on amount of deadheading; no figures (p. 22)	Less fuel consumption per passenger trip mile than private autos or carpools, depending on amount of deadheading; no figures (p. 22).	Operating expenses vary from 1 - 4.5¢ per productive seat mile (p. 11). Variation due to differences in level of service and method of operation. Costs typically 15-25% lower when equipment and drivers leased from charter bus companies rather than transit companies, because charter or sightseeing companies often can use these buses and drivers during off-peak hours, while transit companies usually cannot (p. 13).	Not mentioned.

Overall Evaluation

While increased use of car, van, and buspools will not dramatically reduce urban VMT, encouraging these forms of ride-sharing is, relatively speaking, an important strategy. For one thing, even the limited VMT reduction it offers compares favorably with that associated with other strategies. For example, the TRW evaluation of transportation control strategies for Los Angeles estimates that increased commuter carpools could potentially reduce VMT by about 4.4 percent, which is more than for any of the other strategies they list. Improved transit and a tax on auto use together are estimated to reduce VMT by 4 percent; much improved public transit, and exclusive bus and carpool lanes with a 3¢ per mile tax are estimated to reduce VMT by about 3 percent each; establishing an auto-free zone in the CBD and instituting a 4-day work week are estimated to reduce VMT by only 0.6 percent each (290, p. 170). Furthermore, benefits from transportation pooling programs should materialize quickly, compared to those from most strategies. It has also been suggested that pooling may be particularly appropriate as an interim strategy which can bring about some reductions in auto use until improved transit becomes available. But there will always be some types of work trips for which mass transit service is not suitable or not justified, and where carpooling could play a continuing important role.

Another advantage of this strategy is its relatively low implementation cost. Most carpools have few economic impacts other than reducing members' commuting costs, although employers may need to purchase some computer time if they take advantage of the many good carpool matching routines available, and they may also wish to provide subsidies or other incentives to carpoolers. Buspools, if carefully planned and managed, can usually pay for themselves and may even bring in a profit, making them an attractive venture for private entrepreneurs.

There seems to be general agreement among the references consulted, however, that pooling programs will fail to deliver their potential impact on congestion, air pollution and energy consumption without more concentrated and widely-applied efforts. The present voluntary and largely informal level of pooling efforts is not sufficient to make an impact. An organized effort is needed to coordinate pooling programs, provide adequate incentives for people to join pools, and perform follow-up data collection and analysis to determine how successful specific campaigns have been and to measure the effects on traffic. It would also be useful, as one review points out, to determine the proportion of the driving population that would have to participate in bus and carpools before substantial system-wide efficiencies would be achieved (239).

Government agencies can promote carpools in several ways. First of all, they should collect and disseminate information on successful pooling projects. UMTA has made a good start with the 9 Voorhees' booklets on transportation pooling, now available in a single document (5). DOT and EPA could also jointly carry out a national education and promotion campaign, transforming into a permanent program the temporary all-out nationwide carpool information effort which UMTA and other agencies made during the 1973-74 winter fuel shortage. DOT, EPA and state agencies should make every effort to assure that their employees and government employees in general have the option of joining car or buspools. They could eventually sponsor and support legislation or regulation that would require all large employers to provide carpool matching information for their employees. For example, a proposed Colorado Air Pollution Control Commission regulation would require employers of 50 or more to provide carpool locator service and incentives for use of carpools, bicycles and mass transit, such as reimbursement of parking fees for carpool vehicles and of fares for transit riders, and imposition of parking surcharges for non-carpool vehicles.

The provision of incentives is doubly important when the deeply-rooted aversion many people have towards ride sharing is taken into consideration. One DOT discussion paper (58) refers to the "strange but strong antipathy to carpools for work trips" which, it states, was even experienced during World War II, when this type of measure was generally supported. Some of the more obvious bases for this aversion are the inconvenience of waiting for tardy riders, loss of independence and flexibility of schedule and route, and being compelled to sit close to strangers whose conversation, smoking habits and radio station are not of one's own choosing. These objections may apply less to vanpooling and buspooling than carpooling, but still some kind of incentive program is usually necessary to convince people to change their commuting habits.

The fact that a commuter can save money from joining a carpool is usually not enough of an incentive, even though some estimates of the amount saved are quite impressive. The DOT-TSC paper, "Transportation Energy Conservation Options" (254) estimates the direct savings in out-of-pocket costs are $100-225 per year, equivalent to 15 to 35 percent of the average cost for operating a standard car for 10,000 miles a year, and R. H. Pratt Associates (239) estimate that a carpool with four members saves the user 75 percent of normal automobile commuting expenses. In the majority of cases, however, the potential monetary savings are not enough to outweigh the non-monetary disadvantages of carpooling. Perceptible increases in the cost of driving alone are generally more effective incentives.

There are some indications that the availability and cost of parking have the greatest influence on the number of carpools. For example, in a survey made of the King County (Seattle) assessor's office, it was found that free parking for carpoolers was twice as effective in encouraging carpools as other methods. Parking incentives have the advantage of affecting all income groups more or less equally, of encouraging increased bus ridership as well, and of avoiding the diversion of current bus riders to carpools, since the incentives presumably affect only current parkers. Parking costs can be used as incentives in several ways: fees can be charged to non-carpoolers, reduced or eliminated for carpoolers, or partially or wholly assumed by employers of carpoolers.

Other ways of manipulating costs to encourage carpooling include reducing or eliminating tolls for carpool vehicles on bridges, which would have the added incentive of reducing travel time for these vehicles, or allowing federal income tax deductions for vehicles used in carpools, as proposed in a bill introduced in the U.S. House of Representatives in April 1973. Employers could also provide company vehicles for carpool use or could purchase vehicles specifically for that purpose, as 3M in St. Paul did for its vanpools.

Travel time and convenience incentives could also be created to favor carpools. These incentives could include traffic priority schemes such as carpool use of exclusive or reserved lanes, freeway access via special ramps, or priority on metered ramps. When carpools were given priority on a metered freeway ramp in Los Angeles, the number of carpools using the ramp increased 120 percent in two weeks, and it was estimated that half of these were newly-formed carpools. A combination of reduced tolls and reserved lanes for carpools of three or more on the San Francisco-Oakland Bay Bridge resulted in an increase in these vehicles from 1,000 to 1,800 during the morning peak period.

Though these last measures require some form of governmental action, there are a wide range of measures which individual employers can take, and have already taken in some cases, besides manipulating the cost of company parking as mentioned above. They can provide reserved, indoor or more convenient parking spaces for carpoolers, priority access and passage (applies to companies with large grounds), and convenient loading bays and shelters for carpool participants. Working hours could even be reduced or made more flexible for carpoolers, or employers could directly subsidize carpoolers by reimbursing them a certain amount per mile driven to and from work. Some employers already are subsidizing buspools, as in the case of the National Geographic Society (see Table 3-5, p. 3-14, column 4), or paying all or part of the fare for their employees who use transit, an analogous measure. Most employer measures would involve insignificant amounts of money for the employer, and in many cases would be to his economic advantage, since more carpools mean fewer parking spaces to be constructed or leased.

3M is a good example of a company which has successfully combined incentives to riders—convenient parking at the plant—with very effective incentives for vanpool drivers—a free ride to work, personal use of the van during non-working hours at 7¢ a mile, the right to keep surplus revenue (fares less operating expenses) which averages 93¢ a day but can reach $2.00 a day for a 25-mile round trip at full occupancy, and the option of buying the van later from 3M.

Besides government agencies and private employers, transit operators can also make an important contribution to promoting pooling efforts by cooperating with organizing groups or by themselves getting into the pooling business to their own gain. Unfortunately, transit operators sometimes fear that pooling programs will take riders from them, though most surveys of pool participants show that the majority were former auto drivers. Some transit authorities also seem to feel threatened and resentful that the innovative bus clubs are enjoying such success, while their own ridership levels, until recently, have been declining steadily. In Washington, D.C., for example, one operator has abolished transfers between its buses and the Reston Commuter Bus buspools. The transit operator now not only claims that it cannot supply the Reston group with any additional buses, it has also threatened suit if the group obtains buses anywhere else!

In fact, there is no real basis for transit companies to feel that car and buspool programs are competing with them, since transit companies can in many instances integrate their operations with such programs, or even initiate such services successfully themselves, as in the case of the Los Angeles SCRTD. City transit agencies can encourage the formation of buspools without providing city vehicles or drivers for the pools, as in San Francisco where the Golden Gate BH&T District procures buses and drivers for commuter clubs and will even subsidize them up to $500 a month per bus. Or they can, as in Omaha and Los Angeles, provide buses and drivers from their own fleet and crew and actively promote and advertise these services. The Los Angeles SCRTD subscription bus service is also fully integrated with the city bus system, since commuter passes are valid on all city buses in the CBD and on selected routes near subscription bus pickup points. This type of integration would encourage carpoolers to use transit for off-peak travel, such as company business formerly performed with private vehicles and reimbursed by the company, shopping trips, or trips to and from restaurants. Transit companies could extend the subscription or pooling concept to these working day trips; in McLean, Virginia, for example, a consortium of restaurants has initiated a service (vehicle unspecified) to carry employees from a research park area to any restaurant in the CBD during the noon hour.

Ultimately, transit company involvement in carpooling can follow the example of the Knoxville Transit Authority, which initiated a car and buspool program on its own because it felt that such operations were a natural extension of good transit service. The pooling operations provide valuable insight into the way various modes of transportation can be integrated to the transit company's benefit as well as the public's. KTA found, for example, that information generated by carpool matching programs could be helpful in planning regular transit services, permitting them to locate areas where public transportation could serve as liaison to bus and taxipool service, where bus service is desired and transit routes could be expanded, and where KTA could offer other special pool services. The Knoxville transit company's initiative offers an excellent example of the potential of innovative intermodal integration.

If government agencies, private employers, and transit operators all worked together in individual cities and nationally through industry associations to "give carpooling a good name", commuter auto occupancy could doubtless be increased and many commuters converted to subscription bus or vanpools. The immediate direct effect on VMT might not be very substantial, but it certainly justifies the minimum cost and effort required. Perhaps most importantly, Americans' overwhelming preference for the auto as a work-trip mode might begin to weaken as more Americans discover that they do not dislike sharing their work ride as much as they previously thought. This discovery would incline them to accept para-transit and transit as auto-alternative modes more readily than they would have before.

INCREASE COST OF AUTO USE (3.2)

Introduction

The law of supply and demand states that when the price of a commodity increases, consumers' demand will decrease. The strategy of increasing the cost of auto use seeks to take advantage of this economic phenomenon by increasing elements of auto travel cost in order to decrease demand for this commodity and to encourage consumers to substitute the use of less expensive, more energy-efficient, less polluting modes for auto travel. To the extent that this substitution occurs and total VMT are reduced, this strategy will reduce congestion; however, its overall impact on mobility could be negative if the congestion gains are outweighed by loss of freedom and ease of urban movement due to inadequate supplies of alternative transportation services to absorb diverted demand.

Three ways of increasing auto use cost are examined in this subsection: implementing road pricing techniques (3.2.1); manipulating parking costs (3.2.2), and increasing fuel costs (3.2.3). For all three topics, the data which INTERPLAN was able to locate were found to be sketchy and inconclusive. There is a great need for further generation and analysis of hard, experiential data, as contrasted to theoretical predictions.

In general, the available evidence supports the view that demand for auto travel is inelastic to price changes, i.e., that increasing the cost of auto travel in itself is not a very effective means of reducing it or diverting it to other modes. This conclusion should not, however, be interpreted to mean that pricing should not be used as a policy tool, but rather that policy-makers should have no illusions concerning the impacts of such tools used as restrictive measures alone. Their total impact might also be considered to include the effects of programs supported by any revenues they generate, as in the case of gas, parking, or road user taxes earmarked for transit or other transportation improvements.

Two further comments of an economic nature may help to put this strategy into proper perspective. First, it is a generally accepted economic principle that the most direct pricing policy is the most efficient and equitable. The implications of this principle are that while road pricing is an economically legitimate means of charging road users for congestion costs, some other priceing mechanism more directly linked to vehicle emissions would be a more economically correct way of charging for air pollution diseconomies created by auto travel, and a direct tax on fuel would be the best way of penalizing use of fuel for driving. Therefore, road pricing should not, strictly speaking, be used as a direct means of reducing air pollution or energy use, although some reduction in emissions and gasoline consumption might be expected to occur if a road pricing policy were successful in reducing VMT.

Secondly, when any element of auto use cost is artificially manipulated to attain social goals such as urban mobility, air quality and energy conservation, the gains in terms of these goals should ideally be weighed against any distortions in the production and consumption of transportation goods and services due to the distortion in auto use prices and any losses in welfare due to the proportionally greater impact on low-income groups of increasing the price of a necessary commodity. While it is beyond the scope of this report to delve into these aspects of pricing policy, it is felt that the economic analysis of distortions in resource use and of welfare impacts should not be omitted from an overall evaluation of proposed pricing policies.

Implement Road Pricing Techniques (3.2.1)

Road pricing as a means of limiting traffic in congested areas can take many forms, the most well known of which is a toll barrier excluding the traveler from the roadway unless he pays an entrance (or in some cases, departure) fee. Less well known pricing techniques are:

- The daily license: vehicles are banned from a specified area unless a license valid for that day has been purchased.
- Area and time of day pricing: road users are charged a range of fees depending upon congestion experienced in a given area at different times of day.

The measurement and enforcement of the latter technique is envisaged to be carried out through vehicle metering (not to be confused with the "valving" of traffic onto a roadway as discussed under ramp metering, 2.1.3), for which an instrument mounted on the vehicle is used to automatically or manually record the vehicle's location and the time and length of stay in the congested area, and to calculate the fee. An alternative to on-vehicle metering is off-vehicle metering, which requires the vehicle to be detected, identified, and billed by a central management and computer complex.

EXPERIENCE. Experiential evidence regarding the effect of road pricing on VMT is virtually nonexistent, especially in the United States. The forms of road pricing most frequently practiced are the roadway toll and daily licensing. The toll is the most familiar and has been applied to turnpikes, bridges, and tunnels. Initially, the purpose of the toll was to tax the user in order to recover construction and maintenance costs, not to limit traffic. However, since toll barriers effectively control access to important facilities, tolls can theoretically be used to influence traffic flow and modal choice. A .2 to .4 percent increase in transit use for each cent increase in the toll has been observed at the San Francisco-Oakland Bay bridge (6), but aside from this one observation, no other data relating tolls to traffic has been uncovered by INTERPLAN.

Daily licensing is practiced by various campuses of the University of California, and perhaps by other large landowning organizations unknown to INTERPLAN. Motorists pay a fee at the entrance gate for the privilege of entering and parking on campus. For the casual motorist, a one-day license is sold; for students and employees, monthly or yearly licenses are available. This practice was instituted specifically to reduce campus automotive traffic. Unofficial sources and observations indicate that sightseeing traffic has been effectively reduced by these gate tolls, and that the use of campus roads for short-cuts has been nearly eliminated. However, to INTERPLAN's knowledge, no systematic study of the effects of this policy has ever been made, although such a study could be a rich source of data for analysis and application to related situations.

THEORETICAL STUDIES. There is considerable economic literature on the subject of road pricing, but little more than conceptual work has been done except for some laboratory work to develop meter hardware in England. Indeed, much of the work is limited to discussions of the practical and political difficulties of instituting road pricing, including price-setting, technical means, and implementation costs. To our knowledge, no city in the world has yet introduced full-fledged road pricing.

The question of equitable cost allocation to users is a problem, both philosophically and technically. Martin Wohl, an Urban Institute economist, states in the earlier of his two articles on road pricing that the decision to implement road pricing "must rest on ethical judgments about the redistribution of income" (370). His second paper reinforces this opinion by noting that incremental road pricing could result in a net loss to all road users. Those unwilling to pay the toll will be forced to use alternative, less convenient routes; those who choose to pay may experience less congestion, but at an additional monetary cost (371). Reference 7 underlines this theme by drawing attention to the fact that any road pricing scheme is likely to price the poorest motorist off the road and may cost him his job. This report cites a study investigating the potential effect of pricing policies proposed for a river crossing at Hampton Roads, Virginia where it was concluded that a significant impact upon employment in the region could result.

Most of the conceptual work on how to technically carry out road pricing has been done in Europe. Gabriel Roth* has investigated in considerable detail the mechanics of determining user costs. His grouping of road pricing systems into four categories is summarized in a 1973 DOT review as follows (239):

> "1. Vehicle On-Board Systems - A meter which registers fees is attached to the vehicle; travel costs for the user of this system may be assessed through:
>
> a. Point Pricing - Costs are based on the number of impulses counted by the meter, with these impulses received from electrical cables placed in or adjacent to the roadbed at various pricing points.
>
> b. Continuous Pricing - Authorities would establish differential zones with vehicles being charged for the time or distance traveled in a zone and with zone changes registered by on-board meters. Again, road sensors would be required at all points on the roadway system to indicate zone changes.
>
> "2. Off-Vehicle Systems - Vehicles would be equipped with automatic identification devices which relay information on vehicle movements to a central computing station. Thus, actual calculating of vehicle fees is done off the vehicle. ...
>
> "3. Differential Licenses - Licenses, valid on a yearly or daily basis, allow a vehicle access to congested roads or zones.

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*Gabriel J. Roth, "Paying for Roads: The Economics of Traffic Congestion," Second International Symposium on the Theory of Traffic Flow (London: OECD, 1963), p. 47.

> While cheaper and simpler to use than metering systems, they are not as comprehensive or precise. For example, under this system vehicles making short journeys through congested areas would be charged as much as vehicles making longer journeys in these areas.
>
> "4. Present Road Use Pricing Systems - In addition to charges for vehicle licenses (a fixed charge) there are, and have been for many years, variable fees dependent on the amount the car is used which provide a current form of road pricing. These fees include taxes on gasoline, tolls on toll roads, and parking fees ... . More widespread application is frequently mentioned as a means of implementing and achieving road pricing" (pp. 160-161).

Reference 239 states that the technical feasibility of implementing these road pricing systems is within the state of the art and identifies components needed for each system. The report concludes that, "the major problem is in actually constructing the systems and testing their operation--problems may appear at that time. Until actual demonstrations have been completed, however, further certification of workability must be held in abeyance" (p. 184).

Implementation cost estimates are equally rare and difficult to interpret. Charles Hedges, a U.S. DOT economist, takes a look in a 1969 HRB article (116) at the cost of implementing road pricing via an extension of PULSE (Public Urban Locator System), originally developed under UMTA contracts for the purpose of locating buses and following their movements. The cost of such an extension was estimated to be $100 million for a city of two million people. Reference 239's review of road pricing also discusses implementation cost estimates for two metering systems. The 1972 estimate for a point pricing system in the United States is between $1.2 billion and $3.5 billion. The cost of meters for use in a continuous pricing system ranges from $4.20 to $28.00 per meter, depending upon whether a permanently mounted manual or automatic meter is used, or one which is exchanged for a fee when the purchased time is expended. Off-vehicle system costs for the Washington Metropolitan area were estimated in 1959 to be $60 million (239, p. 175). The cost to implement differential licenses was not estimated but was believed to be "low".

Two more recent examinations of road pricing within the context of EPA-required transportation controls to reduce VMT and vehicle emissions include estimates of road pricing implementation costs and benefits. A Rand study for San Diego (102) investigates the use of a light-duty motor vehicle mileage surcharge as a means of reducing vehicular traffic in congested areas and finds that a 10 percent mileage reduction would require $50 million annualized expenditure. The study also arrives at the following conclusion: "Bus system improvements, no matter how substantial, cannot alone produce mileage reductions greater than 10 percent. We have found that to produce substantial mileage reductions requires a combination approach--both the carrot (improved bus) and the stick (mileage surcharge)." However, it must be pointed out that mileage surcharges, which are more fully discussed under increasing fuel prices (3.2.3), cannot be considered as forms of road pricing unless control of the surcharge can be effected on a regional basis. The Rand study found that it was not a county prerogative to do so under present legislation.

An Alan Voorhees' evaluation of auto use restrictions (3) contains a summary of different control strategies for the city of Boston. It puts road pricing into perspective vis-a-vis other strategies. A user charge of 50¢ per trip within the region is estimated to generate $5.3 billion in agency benefits and $5.4 billion consumer costs, so that the net cost is about $100 million. 1977 emissions would be reduced by 9 percent in the core city and 5 percent in the region. The same study estimates that emissions would be reduced 10 percent by instituting vehicle inspection and maintenance regulations.

IMPACTS AND OVERALL EVALUATION. Road pricing could undoubtedly have a marked effect on VMT and fuel use to the extent that pricing policies were manipulated to that end by government agencies. Costs to the consumer could presumably be adjusted to any level until the desired reduction were achieved. However, as many researchers have pointed out, implementation of this type of non-market pricing in the U.S. may be difficult if not impossible because of the many private and commercial interests that would be adversely affected. Certainly any form of road pricing would have to be accompanied by improved transit service and some means of subsidizing urban travel for low-income families who could not afford higher travel costs.

The economic picture is not at all clear because no practical demonstrations have yet been undertaken to identify actual as opposed to estimated costs. The Boston example in Reference 3 implies that road pricing may generate surplus funds which could be used for transit improvements, providing the city would not simply divert the funds to other uses. The technical feasibility of road pricing is also clouded by the lack of demonstration project results. It is true that the systems envisaged by the sources are within the state of the art, but the simplest system, the manual meter, relies upon user honesty, and those systems which enforce honesty by technological means require a high degree of technical sophistication. It is a moot point whether the MTBF (Mean Time Before Failure) of these systems would be acceptable, especially in view of the current difficulties in maintaining the reliability of such prosaic systems as traffic lights.

Last but not least, road pricing systems which monitor individual private vehicles, such as an extension of the PULSE system described in Reference 116 and to some extent all metered systems, would be, in INTERPLAN's opinion, in danger of violating rights-of-privacy statutes since the data could be diverted to purposes less related to the public interest.

Manipulate Parking Charges (3.2.2)

Parking charges can be imposed on three kinds of parking facilities: municipally controlled spaces, privately owned commercial lots, and free spaces provided for the convenience of employees and customers. The following policy mechanisms have been suggested in the literature.

Type of Facility	Applicable Policy Mechanism
Municipal parking facilities:	
Off-street	• Increase cost/hour directly or indirectly via parking taxes (flat or selective rate based on location, day of week, or elapsed time) • Impose surcharges for all-day (over four-hour) use
On-street	• Increase meter cost/hour
Private commercial lots	• Impose parking taxes • Reduce or remove parking subsidies • Impose surcharges (flat or selective)
Free parking spaces provided by:	
Employers for staff	• Surcharge on employees for single passenger vehicle parking, reduced to half for 2-passenger carpools and to zero for carpools with 3 or more members; subsidize transit-riding employees

Businesses for customers	• Surcharge on owner equivalent to estimated surcharge proceeds from commercial lots • Reduce or remove parking subsidies

Revenues from any of the above parking charge policies may be earmarked for transit service expansion and improvements in order to provide a viable alternative for those whom the parking charge discourages from using the drive-and-park mode.

EXPERIENCE. The documented experience of the effect of these mechanisms on urban auto use is limited and indirect. The reason for this is that, until recently, the pricing of parking was not usually thought of as a means of reducing traffic but rather as a means of rationalizing use of on-street parking and maximizing parking space turnover, from municipal authorities' point of view, or as a means of maximizing income, from the commercial parking lot owners' point of view. Due to a lack of interest in the impacts on traffic of changing parking charges, little or no data on these impacts has been collected.

The usefulness of the available experience relating to parking charges is limited in two ways. First of all, it obviously relates only to lots which actually charge parkers, that is, private commercial and municipal facilities. But these facilities account for only a part of the total parking supply. It has been estimated that private parking provided free of charge accounts for half of the total parking space in the CBDs of many major urban areas and up to 75 percent in some cities (133, p. 6-24). In the Los Angeles CBD, it has been estimated that free or subsidized parking was provided in 1966 for over 50 percent of 208,000 employees, and 85 percent of a national sample of employees in urban areas were found to have free or subsidized parking. Furthermore, although exact estimates are difficult to make, well over half of all auto shopping trips to CBDs appear to use free parking (261, p. 58). By comparison, municipal off-street parking, where increased charges can most easily be applied, represents only 18 percent of the total parking space available in cities with populations over 100,000 (170, p. 5).

The second limitation of experience with this policy is that no firm conclusions can be drawn from the available data because the parameters measured are not always related to impacts on traffic, the effect of parking charges cannot be isolated, or the data base is not very reliable. For example, several cities in the U.S., notably New York and Pittsburgh, have imposed parking taxes of some sort on both municipal and private commercial facilities. However, these have been implemented and raised over a period of years, so that before-and-after results are not clearly observable. By contrast, in San Francisco the Board of Supervisors imposed a 25 percent parking tax throughout the city in October 1970 which remained in force until it was reduced to 10 percent on July 1, 1972, thus providing a potential basis for evaluation of effects. Parking lot operators almost uniformly estimated their loss in trade at 8 to 10 percent, but these reports may tend to exaggerate the true market impact due to the operators' interest in strengthening their case concerning the hardship it imposed on the industry. Actual market elasticity was considered to be markedly lower by transportation agency members, but efforts to verify their observations by examining traffic counts on bridges leading into the city were inconclusive, because simultaneous changes in bridge tolls and service levels made it impossible to isolate traffic changes due to the change in parking cost (170, pp. 22-23).

Experience with the effect of installing parking meters and increasing their rates is documented for London and Washington, D.C. In London, meter rates were doubled or quadrupled for a sizeable proportion of the CBD (1.7 sq. mi.). But measurements of the impact of these rate increases were made only during off-peak hours and in terms of the changes in time required to complete the entire park-and-visit trip. In the areas of greatest rate increases, the time required for the trip was reduced by two-thirds, due primarily to the reduced cruising time needed to find a vacant meter, but speed tests on selected streets showed no important change in average traffic speed after the meter rate increases (116, p. 21; 170, pp. 22-28).

Data from Washington, D.C. shows that the number of parkers in the metered area actually rose by over 2.5 times after the introduction of meters, reflecting the fact that meters provide an easy way of enforcing short-term parking restrictions, causing the spaces to be turned over more frequently (170, pp. 22-23). A similar increase in turnover of 53 percent was noted in mid-Manhattan after increasing meter rates to 25¢/hour (116, p. 22).

The best review of the effects of parking charges, an Urban Institute study (170), concludes on the basis of general experience in a number of U.S.

and British cities that automobile usage is not very sensitive to the imposition of a parking tax, a demand elasticity of around -0.3 being consistent with most experience for work trips and a somewhat higher elasticity for other trip purposes. For work trips, this is said to imply that a parking tax of $2.00/day imposed on an area where parking already averages $2.00/day (an increase of 100 percent) would cause a 22 percent drop in the utilization of taxed parking spaces but a lesser drop in trips made, since some proportion of trips is due to non-parking (through) traffic (170, pp. 43-44). In England, the elasticity of demand for parking has been estimated at less than -0.6 (116, p. 21); an elasticity of -0.6 would imply twice as great a response as one of -0.3.

It was not a lack of quantitative analysis nor of municipal control over parking, however, that prompted the substantial public and Congressional opposition which led to the withdrawal of EPA's parking surcharge regulations. These regulations represent the most comprehensive approach INTERPLAN has seen to the manipulation of parking costs. The surcharge on commercial parking spaces, promulgated in November 1973 for three air quality control regions, would have started with a $0.10/hour increase in July 1974 for parking in the cities, rising to a $0.25 increase by July 1976 to be effective over the region as a whole. Exemptions were to be extended to the handicapped and to disabled veterans, and to facilities used exclusively to service mass transit (park-and-ride lots). Fifty percent of the gross proceeds were to be used for EPA approved or designated mass transit improvements (80, pp. 31236-31237).

Free parking spaces provided for the use of customers by the owners and operators of businesses were to be subject to a surcharge on the owner starting with $180/year/space in July 1974 in the cities and rising to $450/year/space by July 1976 for the region as a whole. Exemptions and the earmarking of proceeds were the same as for the commercial parking surcharge.

For employers providing free parking spaces, the regulations provided for charges to be levied on each employee driving a single passenger vehicle starting in July 1974 in the amount of the average daily parking rates charged nearby plus a surcharge of $1.00/day; this was to rise to the commercial rate plus $2.50/day by March 1977. Half this rate was to be charged for 2-person carpools; carpools of 3 or more were to be allowed to park free of charge.

In addition, employers were to be required to reimburse employees for their expenses in utilizing mass transit facilities in amounts not to exceed $200/year/employee (80, pp. 31247-31248).

However, when the House Committee on Interstate and Foreign Commerce reported its version of the Energy Emergency Act in December 1973, the bill included a provision forbidding the imposition of parking surcharges by EPA without the consent of Congress. In addition, the Committee directed the EPA Administrator to submit a study to Congress within six months on the necessity and desirability of such fees to achieve air quality standards. Although the Energy Emergency Act was not passed, these provisions were taken by the EPA Administrator as firm Congressional guidance on the subject, and, as a consequence, all surcharge regulations were permanently withdrawn (Federal Register, Vol. 39, 15 January 1974, p. 1848).

IMPACTS ON GOALS. The philosophy underlying the manipulation of parking charges is that substantially higher parking rates increase the price of automobile trips and therefore reduce the number of trips demanded. Individuals who are willing to pay the higher fees have an easier time finding a place to park, and this reduction in cruising time alone reduces congestion (116, p. 2). Also, increasing the cost of parking could divert trips from auto to other modes (3, p. 37). The reduction in trips and congestion and the diversion to transit should have beneficial impacts on air pollution and energy consumption.

As documented in the discussion of experience above, there is no direct evidence of these impacts other than the reduction in time spent searching for a parking space in London and Washington, D.C., and the low values estimated for the price elasticity of demand for parking reported in Reference 170. Predictions concerning the expected effects of parking cost increases on vehicle miles traveled and air pollution, shown in Tables 3-7 and 3-8, are more optimistic than the actual evidence might seem to warrant; even so, the magnitude of the predicted effects seems quite low. Most of the sources cited in Table 3-7 give estimates in the 3 to 7 percent range for VMT reductions in the CBD due to parking charge increases in the $1/day range. The regionwide effect of this reduction would be negligible. However, one source estimates an 8 to 16 percent reduction in auto traffic and a 4 to 8 percent diversion of auto trips to transit for a $1/day parking tax (239), and another estimates a 15 percent decrease in auto driver trips and a 13 percent increase

Table 3-7. Predicted effects of parking charges.

Source	City	Amount of Rate Increase	Projected VMT Reduction	Projected Emission Reduction	Projected Transit Ridership Increase
6 p. A-34	Pittsburgh	87¢ daily increase.	5.3% in CBD.	Not mentioned.	Not mentioned.
3 pp. A-7, A-8	Baltimore	From current $1.83 per day to $2.50 per day.	7% in CBD; negligible (1%) regionwide.	Same as VMT reduction.	Not mentioned.
3 p. 37	Boston	$1 per day increase.	3% in CBD; .5% regionwide.	Same as VMT reduction.	Not mentioned.
7 p. 3-36	Canberra, Australia	$1 per day increase.	Not mentioned.	30% in town centers; 40% in central area.	Not mentioned.
133* p. 6-18	Washington, D.C.	Parking rates doubled. Rates for all spaces tripled or quadrupled.	Minor reduction —not more than 5% Motor vehicle traffic might be reduced 20-25%.	Same as VMT reduction.	Not mentioned.
239* p. 184	Washington, D.C.	$1 per day tax.	8-16% reduction in auto traffic.	Not mentioned.	4-8% of reduced auto trips diverted to transit.

*Compare with projections in Table 3-8.

Table 3-8. Projected changes in travel behavior resulting from a parking tax in Washington, D.C.

Increase in Average Parking Cost	Percentage change in Auto Driver Trips	Transit Trips
$.25	-4	+3
.50	-8	+6
.75	-12	+10
1.00	-15	+13
1.50	-20	+20
2.00	-23	+26
2.50	-26	+33
3.00	-29	+38
3.50	-31	+42
4.00	-34	+47
4.50	-36	+51
5.00	-37	+55

Source: Ted Erlich, "Transportation Pricing and Parking Charges," paper presented at the meeting of the Highway Research Board's Committee on Taxation, Finance, and Pricing, Washington, D.C., January 1973.

Reproduced from Reference 170, p. 33.

in transit trips for the same increase in parking cost in the same city (Washington, D.C.) (170; see Table 3-8). The last-mentioned reference expresses the change in auto and transit trips as a function of parking charge increases, and predicts a 37 percent drop in driver trips and a 55 percent increase in transit trips for a $5 increase in parking costs.

Any evaluation of these predicted impacts, which are minor except when parking rate increases are substantial, must be tempered by consideration of the limitations and drawbacks of implementing this policy, which fall into five main groups, all but the first of which also applies to the related action of limiting parking spaces (3.3.2; see p. 3-70 ff.):

1. Any kind of tax, including a parking tax or surcharge, is politically unpopular.
2. If the increased parking charges are effective, they impact on only a portion of CBD trips.
3. The increased charges may simply shift traffic without reducing it.
4. Increasing parking charges could actually increase congestion.
5. Other pricing techniques would be more effective and more equitable.

The first barrier to a parking tax would be getting the tax approved by local voters or governing bodies. Even if the community were basically in favor of such a policy, some city administrators might feel that earmarking parking tax receipts for transit improvements, which are unquestionably required if the parking tax is to be effective and reasonably fair, would result in an unwelcome diversion of potential general revenue for other municipal uses.

The second barrier would be to ensure that the tax covers a large enough area to have a meaningful impact on traffic. Since 15 to 30 percent of vehicular traffic in the greater downtown area, defined as being 4 times as large as the CBD, passes through without parking (170, p. 18), a uniform reduction of, say, 25 percent in the number of parkers in this area would reduce traffic by 17 to 21 percent (25 percent x [100 - 15 to 30] percent). However, if the tax applied only to the CBD, where 60 percent of traffic is through traffic (170, p. 43), a 25 percent reduction in parkers would reduce traffic by only 10 percent (25 percent x [100 - 60] percent).

A parking policy based on high charges may result in a change in the type of parker rather than a change in the volume of parking. Short-term parkers would replace long-term ones; parking shoppers would replace people who drive to work and park (116, p. 21). Likewise, parking controls for only small portions of the CBD would simply shift parking demand to the surrounding area, because a great many destinations within the area would be within easy reach of parking outside of the controlled area, and many parkers would be able to escape parking controls (170, p. 18).

Increasing parking charges could increase congestion in three ways. First, congestion may increase due to faster turnover of parking spaces; this possibility is mentioned by two sources (116, p. 22; 170, pp. 23-24). Secondly, backhaul trips may be created due to diversion of drive-and-park trips to delivery or taxi trips. If parking restraints are severe, many trips which previously ended in the controlled area may become "deliveries"; for example, one family member driving another to work and then returning without parking (170, pp. 17-18). As a result, an additional backhaul trip is created for every trip which becomes a delivery. The same effect would result from a shift to taxis: if the price of parking suddenly shot from, say $2.00 to $4.00, some people who formerly drove and parked their autos would find taxis cheaper or more convenient, and taxi traffic would increase. This simply replaces one of the trips made by auto by another auto trip—plus an extra return trip (170, pp. 43-44). Thirdly, as congestion is reduced by parking controls, trips which formerly bypassed the parking restraint area may now find it worthwhile to travel through it (170, pp. 17-18).

Higher parking charges probably would not be as efficient an alternative as marginal-cost pricing techniques because the charges would bear no relationship to the distance traveled nor to the type of roads used, and if congestion in the central city were reduced, additional through traffic, which pays no parking fee, might be attracted. Thus some trips that did not contribute to congestion would be discouraged, while some new non-paying, non-parking traffic would be encouraged (116, pp. 21-22). For example, vehicles making through trips or pickups (deliveries) would escape the parking surcharges though they contribute to traffic as much as or more than vehicles destined to park (164, p. 412).

OVERALL EVALUATION. The balance of evidence and opinion seems to indicate that manipulation of parking charges per se is not likely to reduce congestion measurably. To the extent that parking charges can be implemented in ways that encourage carpooling, improve traffic flow, and shift drivers to transit modes, however, congestion and air pollution may be reduced and energy consumption diminished. While parking taxes cannot be effective as a stand-alone policy, they are a valuable companion to efforts directed at increasing transit and para-transit use, because they contribute both a "carrot", by raising funds to improve transit, and a "stick", by increasing the cost of the auto mode for parking-destined trips.

Increase Fuel Costs (3.2.3)

INTRODUCTION. Artificially increased consumer fuel costs are generally assumed to result in VMT reductions. An artificial increase may occur due to a surcharge or tax imposed upon the market price or to manipulation of market price by control of supply or by other means that effectively make fuel more expensive and presumably driving less attractive to the consumer. This discussion first presents experiential data, then reviews studies which have forecast the impact of fuel costs on VMT, and finally comments on the effectiveness and advisability of raising fuel costs as a strategy.

EXPERIENCE. The experiential data base available to INTERPLAN is scant, primarily due, it is believed, to the fact that substantial increases in fuel cost beyond the expected inflationary increase are a new phenomenon, the effects of which are still under examination. The analytical task is complicated by the concurrence of increases in fuel cost and reduction in fuel availability. Thus, the analytical differentiation between the effects of increased cost and fuel shortage upon reduced VMT is still incomplete. However, the effects of the winter 1973-74 fuel problem have been noted, differentiated or not, by several observers.

One bit of historical evidence should be mentioned to indicate an important underlying trend predating the oil embargo which transformed the impending fuel shortage into a crisis. Gas use had been steadily increasing since 1965 due to increases in car size and the addition of emission controls, automatic transmissions, large engines, power steering and air conditioning. A UPI item of June 1973 sets the increase in fuel demand by new cars in 1973 attributable to these causes at 20 percent over 1965 fuel demand ("New Car Attraction Isn't Low Mileage," Santa Barbara News-Press, 10 June 1973). It can be deduced that drivers with new autos were willing to buy 20 percent more gasoline than they did in 1965 in order to have larger, cleaner, more comfortable cars.

In October 1973 the oil embargo created both a critical fuel shortage and a sharp increase in fuel costs. Consumer reaction was to cut auto travel and switch to other modes. An article appearing in the San Francisco Examiner & Chronicle in February 1974 (146) noted that "the public has been turning to buses this winter—passengers over the Bay and Golden Gate bridges increased nearly 20 percent compared with a year ago." In March 1974, a Los Angeles Times article observed that freeway use in some areas was down by 33 percent, and commuter and regular traffic by 9 percent. Further, "the customary Friday evening rush of campers and trailers heading out of the metropolitan area was down 25%." Downtown parking lots saw a reduction in volume of business; one operator said 45 percent of his regular customers stopped driving their cars. Sunday travel was down 33 percent, indicating a sharp reduction in long-distance and recreational driving. Carpooling was estimated to have increased 10 percent (Ray Hebert, "Decline in Traffic Holds Good & Bad News," Los Angeles Times, 11 March 1974).

In June 1974 a major study of the regional impacts of near-term transportation alternatives in Los Angeles by Rand (W. T. Mikolowsky et al., The Regional Impacts of Near-term Transportation Alternatives: A Case Study of Los Angeles (R-1524 SCAG), prepared for the Southern California Association of Governments [Santa Monica, Calif., June 1974]) noted that by early 1974 much recreational travel had been eliminated (no figures given). Further, it stated that a 15 percent increase in bus ridership had been observed by the Southern California Rapid Transit District. The report claims a correlation between the increase in the real market price of gas and the effect predicted by a previous Rand transportation model: "with the 60¢ per gallon price of gasoline included, the increase in ridership predicted by the model as a result of a flat 25¢ (bus) fare is about 30 percent. Thus we are in nearly exact agreement with the range of observed data for this particular transportation management tactic."*

Several references have observed that recreational travel was sharply reduced during the energy crisis. However, one source notes that in some areas, vacationers merely shifted their mode of transportation to planes, buses, and trains. A June 1974 Associated Press item in the Los Angeles

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*Assuming that at the time the model was prepared, the flat 25¢ bus fare was a postulated figure, whereas the 60¢ gas cost was real. Thus the apparent discrepancy between the observed 15 percent increase and the predicted 30 percent increase in bus ridership.

Times (Bill Saul, "Shift Away from Cars on Vacation," Los Angeles Times, 23 June 1974) cited reports from the Southern Nevada Resort Association that "bookings took a mild beating for the past three or four months because of the gas crisis, but--the loss was usually less than 1 percent and never less [sic] than three." The Southern California Visitors Council observed that "the bodies are coming, but there has been a shift away from auto travel to planes, buses and trains. The net effect is that we are predicting a very good 1974." The article further reports that other tourism-dependent areas such as Reno, San Diego and San Francisco are equally optimistic, although some are engaging in intensive advertising campaigns to encourage auto travel by stressing the present availability of gasoline.

The U.S. Department of Transportation reported in the Los Angeles Times in November 1974 ("Car Travel Declines; Bus, Train Use Rises," Los Angeles Times, 11 November 1974) that auto travel decreased during the first two quarters of 1974 compared with the same period of 1973, as shown in Table 3-9. No attempt to correlate the results with fuel shortages or price increases was mentioned in the article.

Table 3-9. Comparison of auto, rail, air and bus travel in 1973 and 1974.

	Travel during 1st two quarters 1973 (millions)	Travel during 1st two quarters 1974 (millions)	Percent Change
Auto VMT	500,000	467,000	- 6.6
Rail passengers	125.6	140.1	+11.5
Air passenger miles	82,300	85,400	+ 3.8
Intercity bus passengers	60.6	64.0	+ 5.6

In terms of fuel use reduction, the temporary crisis has apparently had a lasting impact. In California, figures compiled by the State Board of Equalization in December 1974 indicated that since April 1974, Californians have settled down to buying between 3 and 4 percent less gasoline per month than they did in 1973, compared to 12.6 percent less in the month of March. After holding steady at about 9.5 percent for the first three months of 1974, gas savings leveled off in the 3 to 4 percent range during the April to September period. Gasoline sales in California for the first 9 months of 1974 totaled 7.4 billion gallons, about 430 million gallons less than in the same 1973 months (Dan Fisher, "The Auto Scene," Los Angeles Times, 2 December 1974).

All the above evidence for impact on auto and fuel use of the recent crisis, however, simply reports the total change observed, and may reflect a trend toward use of smaller, more economical cars, as well as a reduction in VMT. The only review of past experience in INTERPLAN's file to differentiate between the effects of higher price and lower supply was found in a report prepared for the CalTrans Division of Mass Transportation in August 1974 (Timothy J. Healy, Energy Use of Public Transit Systems [DMT-002], State of California, Department of Transportation [Sacramento, Calif., August 1974]). Because of its uniqueness, the text is quoted in its entirety (pp. 8-9):

> "There are at least three reasons why people tend to change their driving habits, either cutting their travel, or seeking alternative travel modes. The reasons follow.
>
> 1) Fuel becomes scarce
> 2) Fuel becomes expensive
> 3) Fuel is rationed
>
> "In the fuel shortage of the winter of 1973-1974, the first two reasons applied. The third factor, rationing, was not really operative since any individual could obtain all the fuel he wished if he had the time and the patience.
>
> "It is too early to assess in detail the total effect of the recent fuel shortage, and how people responded to it. We will need extensive studies which have not as yet been performed. We can, however, make some guarded comments based on our experience and some very limited data. We first present some data. It must be recalled that the major gasoline shortages in the State of California began in December of 1973, increased in January and February of 1974, and peaked in March. By April, shortages began to disappear rapidly and in May, the situation was back to about normal in terms of supply. The price of gasoline, however, had risen by 15 to 20 cents per gallon, which is close to 50 percent.
>
> "The decline in the use of California State highways and freeways in the first five months of 1974, compared with the same months in 1973, is shown in table [3-10] [*].

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*"Fifth Monthly Summary of District Activities Involving Transit, Car Pooling, the EPA, and Certain Impacts of the Energy Shortage," Department of Transportation, State of California, June 7, 1974.

Table [3-10]. California vehicle miles in 1974 compared with 1973.

	Urban Freeways	Rural Freeways	Average for State Highways
January	- 0.9%	- 7.2%	- 3.4%
February	- 0.4	-13.2	- 9.3
March	-10.3	-20.8	-14.9
April	0.0	- 8.8	- 4.6
May	+ 1.1	- 2.7	- 1.4

"It appears that urban freeways, used primarily for commuting, were not greatly affected, except during the very critical month of March when the greatest shortages were experienced. Rural freeway traffic decreased significantly, suggesting that drivers cut their recreational and vacation driving. This also tends to be substantiated by other California State Department of Transportation studies which indicate that weekend travel decreased somewhat more than weekday travel.

"An indication of transportation mode shifting in the face of the energy shortage are the patronage figures for the BART system, shown in table [3-11] [*].

Table [3-11]. Average daily BART patronage, 1974.

	Patronage
January	65,500 passengers/day
February	70,358
March	80,413
April	72,350
May	68,300

"The coincident decline in Urban Freeway traffic and the surge in BART patronage in March of 1974 is, of course, striking. Of equal interest is the return to near-normal when the gasoline shortage eased.

"In addition to the above limited but 'hard' data, this author has also discussed informally the vacation driving habits of the public during the summer of 1974 with persons from a number of states. The general conclusion is that people tend to be making more short vacation trips and fewer long-distance interstate stips. This is in spite of the fact that fuel availability is very good. However, prices are up quite significantly.

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*Private communication with Mr. Ward Belding, Bay Area Rapid Transit District, Oakland, Calif., June 12, 1974.

> "From the above limited data, some of which is quite 'soft', we are led to two very preliminary conclusions about the effect of fuel shortages on driving habits.
>
> 1) The public's use of fuel appears to be quite sensitive to (or elastic with respect to) the convenience of obtaining the fuels. It seemed to be the long lines which cut fuel use in the winter of 1974.
>
> 2) The public's use of fuel appears to be quite insensitive to price for local working and shopping trips. It may be price-sensitive for long vacation trips."

IMPACTS ON GOALS. The use of artificially increased fuel costs had been considered as a strategy to reduce pollutant emissions for some years before the energy crisis of 1973-74. The perceived necessity to reduce energy use and the continuing legislative requirement to reduce air pollution have reinforced interest in the use of fuel surcharges as a means of simultaneously attaining both goals. As a result, many studies both before and after the critical energy crisis have directed their attention toward constructing models to predict VMT reduction as a function of increased fuel cost. Some even attempt to evaluate the social cost of such a policy.

The earliest report reviewed, published in January 1973, examines the question of using high taxes to limit fuel sales (106). It concludes that (pp. 53-56):

> "There is little empirical data for using high taxes to limit fuel sales. All evidence indicates that the price demand elasticity for gasoline is very small. In some European countries where fuel costs are the equivalent of $.80 to $1 a gallon, the use of the automobile is increasing at 10 to 20 percent per year. ... Large increases in vehicle usage are occurring in areas where income levels are much lower than in the SCAB [South Coast Air Basin], and effective public transit systems are available.
>
> "If the people of the South Coast Air Basin should select a high gas tax as a method of reducing travel by 20 percent (or a lesser percentage for that matter), additional research would be required to develop a recommended taxing level. Using some demand forecasts developed by others, it is possible to at least indicate an order of magnitude of the price elasticity of demand for motor fuel. It is in the range of 0.16 to 0.07. Using 0.10 as an arc elasticity over the

> range in question, then the price of gasoline (including tax) would have to be increased by 200 percent in order to achieve a 20 percent reduction in the fuel sales. If the goal required a 30 percent reduction in the fuel purchased by individuals, then the price would have to be increased by 300 percent. This means that fuel now costing $.38 per gallon would have to be priced (or taxed) at about $1.10 per gallon to reduce consumption by 20 percent, or about $1.50 to achieve a 30 percent sales reduction.[*]"

A UPI item appearing in June 1973 ("New Car Attraction Isn't Low Mileage," Santa Barbara News-Press, 10 June 1973) supports this view. It states that "some experts don't see higher fuel prices causing much change in the nation's driving patterns." An opinion of Dr. Paul F. Chenea, General Motors vice president in charge of research laboratories is quoted in support:

> "Higher gasoline prices will undoubtedly encourage car pooling on work days, but probably won't discourage movement of city dwellers into the suburbs--often increasing the distance they must drive to their jobs ... .
>
> "Higher gasoline prices will undoubtedly quell the urge for a casual drive in the country, but probably won't discourage the annual vacation trip that rolls up a few thousand thruway miles ... ."

Reports dating from later in 1973, however, present a more optimistic view of the potential impacts of higher fuel prices. In December 1973 a Rand report summarizing research on the San Diego Clean Air Project included a light duty motor vehicle mileage surcharge as one of the strategies effective in reducing VMT (102). The report concludes that a surcharge (added to the gas tax) would provide an incentive to switch to carpool or bus and to forgo trips. In arriving at this conclusion, the report introduced the concept of the person-trip as a unit measure responsive to the effect of surcharges. Since person-trips can be classified as either essential (home-work trips whose total number will remain constant regardless of constraint, though the modal split may vary) or non-essential (other trips, such as recreation, whose total number will vary with service quality and cost), it is possible to gauge the effect of strategies to reduce VMT and to consider their social costs.

> "When people are forced to alter their normal behavior by forgoing trips or switching to less desirable modes, they experience a social cost; this *social cost of forgone travel* reflects the

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[*] These estimates are extended far beyond any available empirical data and are given only to indicate that the price elasticity demand for motor fuel is very inelastic.

> loss in benefits, convenience, and time as a result of switching from low-occupancy auto to alternatives such as bus or carpool. Now, since 'social-cost meters' have not yet been invented and general welfare functions have not yet been developed sufficiently, no one really knows how to measure this social cost explicitly and exactly. We believe that the best simple proxy (easy to compute, easy to understand) for this social cost is the number of trips forgone because of a particular strategy" (102, p. 32).

Although a mileage surcharge is considered highly effective in terms of reducing VMT, this policy was considered infeasible for San Diego County because it would have required state action. In other words, local manipulation of gas cost was considered "not a county prerogative". For this reason, fuel surcharges were not included in any of the "superior" strategies advanced for the San Diego case, and material supporting conclusions about the sensitivity of person-trips to the cost of fuel was not included in the report.

After the fuel shortage began in earnest, even more favorable views of the efficacy of a gas tax were published. A Los Angeles Times story (John F. Lawrence, "Tax Could Cut Gas Thirst 15%, Study Finds," Los Angeles Times, n.d. [winter 1973-74]) cites a then unreleased study prepared for two governmental bodies:

> "The study suggests that gasoline consumption would react significantly to any increase in cost. Adding 10 cents a gallon would cut next year's expected consumption at least 4.5%, the study concluded. A 20-cent increase would save 7.9% to 9.7%; 30 cents, 10.7% to 14.8%, and 40 cents, 13% to 19.9%, according to the study. The effects would increase in the following year, it said."

In June 1974, Rand released a study of the near-term transportation alternatives for Los Angeles (Mikolowsky et al., *op. cit.*) which adapted many of the study methods and analytic conclusions of the San Diego study published six months earlier (102). The Los Angeles study, however, seriously considers the inclusion of artificially increased fuel costs in a program concerned with the dual goals of reducing pollution and energy consumption. Two of the report's six strategies include increases in gasoline prices as a lever for accomplishing these goals, and the transportation model has been modified to include the gas price effect. The report also considers the social cost of the price increase in terms of trips forgone which "can be used to represent the loss of personal mobility brought about by the implementation of such tactics." In order to reduce the social cost of fuel price manipulation, it is necessary to inaugurate significant improvements in alternative modes of transportation at the same time that methods to enforce the reduction of personal auto use are introduced.

The Rand report concludes that the effect of a unit increase in fuel prices on VMT is liable to be short-term, since consumers, in order to relieve themselves of the burden of increased fuel costs or reduced mobility, may simply shift their auto usage to less gas-hungry cars but continue to drive as many miles as before. Continued improvement in the gas economy of autos is likely to further reduce the effect of increased gas cost upon VMT, but will impact favorably on the goal of petroleum conservation. While incremental fuel cost increases can therefore catalyze a long-term trend toward greater fuel economy without necessarily reducing VMT, in order to achieve the desired goal in pollution reduction fuel taxes would have to be continuously increased, bringing gas costs perhaps to 90¢ per gallon in order to keep VMT at the desired level. The report points out that these high charges would be necessary to reduce pollution because increasing fuel economy does not necessarily reduce vehicle emissions: a large gas-guzzling car is required to meet the same emission standards (g/mi.) as a smaller, more fuel-efficient vehicle. This conclusion assumes that fuel savings from lesser fuel price increases will meet the desired conservation goal, while desired emission reductions will require enough of an increase to substantially affect VMT. It is conceivable that such increases would also be necessary to attain gasoline savings targets.

The authors of a later Rand study sponsored by NSF, which looks at national energy policy, hold to the line that increasing fuel prices is the only way in which energy usage can be significantly reduced; that technological improvements will significantly increase the fuel economy of autos; and that the public will buy these more economical cars in preference to others when replacement time comes (Dan Fisher, "Rand Study Urges Gasoline Tax Hike to Cut Consumption," Los Angeles Times, 1 November 1974).

The now widespread support for increasing fuel cost as a means of reducing VMT is still viewed with caution by at least one recent source. The CalTrans report (Healy, op. cit.) which was written in August 1974 notes that the historical data base for determining the effect of gas price increases upon reduced VMT is "soft". The author of this report feels that the observed reduction in the public's use of fuel is related more to the *convenience* of obtaining fuel than to its *cost*. There will be no lack of future opportunity for data collection and analysis, since there is little doubt that fuel prices will continue to rise. Frost & Sullivan, Inc., a New York market research firm, has predicted that gasoline costs will rise to 96¢ per gallon in 1980, exclusive of added taxation, and that a 15 percent reduction in fuel usage will also occur. Further, the firm estimates that the "nation's bill for maintaining automobiles, without considering inflation, will rise 63% as owners hang on to their older cars and spend more to keep them in shape" (Dan Fisher, "The Auto Scene," Los Angeles Times, 25 November 1974).

OVERALL EVALUATION. In reviewing the references that cover the experiential and predicted effects of manipulated fuel costs upon pollution and energy usage, the following salient points can be isolated:

- Experiential data appears to be based primarily upon observations made during the fuel crisis of 1973-74.
- Predictive data appears to be based upon elasticity models, but the data bases and assumptions upon which these models are based are not made clear.
- The results of the predictive studies are not entirely consistent. In fact, two references contradict the popular trend (106, and the June UPI item), and one study says the data base is insufficient (Healy, op. cit.).

INTERPLAN cites one case to illustrate our observation that many demand elasticity models are probably based on the 1973-74 "fuel crisis" experience. A Los Angeles Times story dating from the winter 1973-74 fuel shortage (Lawrence, op. cit.) describes a study reporting a series of fuel savings as a function of increased costs per gallon of gas in 10¢ increments. Taking the first differential of the mean percentage decrease in fuel usage cited in the article yields an average 3.7 percent decrease for every 10¢ per gallon increase applied. Referring to Table 3-10, which is experiential data taken from the CalTrans report (Healy, op. cit.), it can be seen that the decrease in VMT from the first two quarters of 1973 to the first two quarters of 1974 was 6.6 percent, while the price of fuel rose from 40¢ to 60¢ per gallon, or a 3.3 percent decrease per 10¢ per gallon increment. While this comparison should not be interpreted as evidence that the unspecified data source of the study reviewed by Lawrence was in fact actual fuel crisis period data, since different units are used (VMT vs gallons) and the base price of gas is not normalized, the two percentage increases (3.3 percent and 3.7 percent) are similar enough to raise the question.

If the predictive elasticity models are based on fuel crisis data, then several criticisms apply:

- The 1973-74 experience in fuel savings is the result of two variables changing simultaneously—supply and cost. Elasticity calculations performed may not have differentiated between these two variables if the 1973-74 experience was used as a normalizing base, or may not have sufficiently isolated the individual effects.
- Verification of the elasticity calculations by unambiguous experience with rising gas prices and no supply restraints, or by controlled experimentation, is lacking, at least in the data found by INTERPLAN.
- Elasticity results may err on the side of optimism (significant VMT reduction as a function of increased price) if the willingness and ability of the consumer to buy new, more economical autos to avoid loss of mobility and higher fuel costs is not taken into account. Effectively, at least some portion of the price of a new car bought expressly for these reasons can be considered a measure of consumers' apparently irrational desire to substitute capital costs for operating costs. The price elasticity of demand for gasoline may, in the long term, have little bearing on VMT reduction unless fuel prices increase beyond the point where the public can retain mobility at the same annual fuel cost by purchasing more economical cars.

In summary, it appears from the data that INTERPLAN has gathered that the contention that increased fuel prices will simultaneously result in fuel conservation and VMT decreases sustainable over the long run is based more on theory than on hard evidence. Intuitively, raising fuel costs must have some effect on consumer behavior, but the magnitude of the effect for given discrete increments is not known. INTERPLAN suspects that the American consumer may be willing to absorb far greater increases in cost to retain his perceived mobility than elasticity calculations have indicated.

With the intention of pointing out potential gaps in the state of knowledge about increasing fuel prices, INTERPLAN would like to close this discussion by urging that the possible economic side effects of artificial fuel price increases be thoroughly considered prior to policy decisions. Rand acknowledges that one of these effects will be a reduction in "non-essential" person-trips, which carries a social cost. The report reviewed by Lawrence in the Los Angeles Times implies that increasing gas cost would have a minimal effect on lower income groups and mentions data from work by the Survey Research Center of the University of Michigan. A Los Angeles Times interview with Rand authors (Dan Fisher, 1 November 1974, op. cit.) states just the opposite: "The researchers conceded that the biggest burden of increased gasoline taxes would be carried by low and middle income groups—those making less than $13,500 a year." Thus, the economic side effects upon the less well-to-do segments of the population are yet at issue. The question of the morale of a nation burdened by enforced restraints on mobility is not addressed by anyone, and should perhaps be evaluated by policymaking bodies.

Additional side effects may impinge directly upon those supplying fuel, those who realize revenue from the sale of fuel, and those whose livelihood depends on unrestricted mobility. Whether gas station operators' incomes will decrease depends on whether the decrease in gallons bought offsets the increase in income per gallon. As for the shift in revenue structure, it has been estimated that the combined effects of anti-VMT and anti-energy use strategies will result in a $58 to $223 million loss in annual tax revenues for the Los Angeles area alone, depending upon the mix of strategies, only two of which contain a revenue-creating mileage surcharge (Mikolowsky et al., op. cit., p. 52). The revenue loss is more than offset by the revenue gain for the strategies which include a mileage surcharge, but the question of equity remains.

The impact of fuel price increases on those who depend on mobility, particularly the entertainment industry, is even less well understood. According to an Associated Press news item ("8.1 Billion Gallons for Play in U.S. Last Year," Santa Barbara News-Press, n.d. [late 1973]), Americans used 8.1 billion gallons of gasoline for recreation in 1972, approximately 3 percent of total gasoline usage. Of this amount, going to the movies accounted for 9.2 percent; sports, 14.6 percent; pleasure flying, 10.2 percent; and vacation travel, 66 percent. While a summer news item (Saul, Los Angeles Times, op. cit.) notes only small reductions in business as a result of the 1973-74 crisis, entertainment areas so reporting are high-density areas where the vacationer can walk or use local transportation to enjoy a spectrum of activities once he has arrived. INTERPLAN has no information about the widely dispersed resort areas, camping grounds, and vacation home areas, although informal reports indicate a severe impact, indicated in part by the number of mobile home producers going out of business.

Finally, INTERPLAN's intuitive feeling is that the demand curve of auto travel as a function of gas cost is not smooth. There may be discontinuities or thresholds at which consumers decide to substantially curtail certain auto activities, resulting in a sudden uncontrolled economic displacement. The recent sudden drop in auto sales is a case in point.

RESTRICT ZONAL ACCESS (3.3)

Introduction

Restricting zonal access is the most extreme and direct form of reducing urban auto use; extreme because it is physical in nature, and direct because it is implemented in a precisely defined area. While the carpooling strategy (3.1) uses moral suasion and some economic and convenience incentives to alter occupancy patterns, and pricing techniques (3.2) rely on economic means to alter travel demand patterns, restricting zonal access works by decree: "thou shalt not enter this area during these hours" or "thou shalt not park here". Therefore, while it is less dependent on consumers' choice for its effectiveness, its applicability is more restricted. Zonal access can be restricted only in areas where alternative transportation can easily and acceptably be substituted for the excluded cars, and where the resulting decrease in traffic creates external benefits for retail business in the form of sales and for employees in the form of a more pleasant and safer environment. The designated area must be able to continue to perform its functions even though traffic is banned or parking restricted; this is obviously not true of many high congestion areas such as commuter freeway corridors.

Zonal restrictions also impact on different trip types and trip portions than carpooling and pricing techniques. Carpooling affects the entire work trip; pricing could be applied more selectively to the most congested traffic situations, which again would occur primarily on commuter corridors during rush hours and perhaps also on weekend vacation corridors during peak departure and return times. Restricting zonal access, on the other hand, applies equally to all trips destined for the restricted or no parking zone, but only to a small portion of the total trip. Restricting access or parking in an area containing a high percentage of regional trip ends, such as a downtown or other major activity center, therefore, may relieve congestion and improve air quality in that area, but it has little or no effect on the major portion of the trips made to reach the area. Only when parking restrictions are specifically designed to discourage a particular trip purpose is it likely that auto trips into the restricted area would be discouraged or diverted to transit. Otherwise, restricting vehicle movements or parking will simply shorten trips to the area by the distance between the ultimate destination and the boundary of the restricted zone. In short, restricting zonal access is a very effective tool for "point"-type congestion and air pollution problems; other strategies are better designed to treat "corridor"-type congestion and air pollution.

Institute Restricted or Vehicle-Free Zones (3.3.1)

EXPERIENCE. There are two basic approaches to restricting vehicular traffic: creating some sort of pedestrian zone, usually established as a means of preserving a historical central area or revitalizing a deteriorating CBD; and dividing an area of the city, usually the central core, into traffic cells. Table 3-12 lists 161 cities known to have created zones of either type by 1972.

Table 3-12. List of 161 cities with vehicle-free zones or pedestrian precincts in 1972 (permanent exclusion of all vehicular traffic except where noted).

Austria (4)
- Klagenfurt
- Salzburg
- St. Pölten
- Vienna

Belgium (2)
- Brussels[1]
- Liège

Denmark (15)
- Aalborg
- Ballerup
- Copenhagen
- Federicia
- Helsingør
- Hoistebro
- Horsens[1]
- Hørsholm
- Kolding
- Naestved
- Nyvøbing
- Odense
- Randers
- Svendborg
- Viborg

Finland (1)
- Helsinki

France (16)
- Amiens[1,2]
- Aix-en-Provence[1,2]
- Avignon[1]
- Bordeaux[1,2]
- Cherbourg[1]
- Dieppe[1]
- Grenoble
- Lille[1]
- Marseilles[1,2]
- Metz[1,2]
- Mulhouse[1,2]
- Paris[1]
- Poitiers[1]
- Rouen
- St. Etienne[1]
- Thionville[1]

Germany (47)
- Augsburg
- Baden
- Berlin
- Bielefeld
- Bochold
- Bochum
- Bonn
- Braunschweig
- Bremen
- Castrop Ranxel
- Dortmund
- Duisburg
- Düsseldorf
- Essen
- Esslinger
- Frankfurt
- Gelsenkirchen
- Hamburg
- Hameln
- Hanover
- Heilbronn
- Hildesheim
- Itzehoc
- Karlsruhe
- Kassel
- Kiel
- Krefeld
- Cologne
- Lübeck
- Lüneburg
- Mainz
- Munich
- Münster
- Neuss
- Nuremberg
- Oldenburg
- Osnabrück
- Regensburg
- Salzgitter
- Solingen
- Stuttgart
- Ulm

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[1] Selective traffic ban (during certain hours of the day or exempting certain categories of vehicles).
[2] Temporary ban.

Table 3-12. (continued)

- Wiesbaden
- Wolfsburg
- Wuppertal
- Würzburg
- Wilhelmshaven

Italy (5)
- Florence
- Perugia
- Rome
- Venice
- Verona

Ireland (1)
- Cork

Japan (1)
- Tokyo[1]

Netherlands (20)
- Arnhem
- Amsterdam
- Apeldoorn
- Breda
- Deventer
- Dokkum
- Eindhoven
- Enschede
- Grovingen
- Haarlem
- The Hague
- Heusden
- 's-Hertogenbosch
- Hilvervn
- Maastricht
- Meppel
- Roosendaal
- Rotterdam
- Utrecht
- Zwolle

Norway (2)
- Oslo[1]
- Trondheim

Portugal (1)
- Lisbon[1, 2]

Sweden (2)
- Göteborg[1]
- Stockholm

Switzerland (7)
- Bern[1]
- Geneva
- Lausanne[1]
- Lucerne[1]
- St. Gall[1]
- Winterthur
- Zurich

United Kingdom (12)
- Antrim (N. Ireland)
- Bolton
- Chichester
- Leeds
- Liverpool
- London
- Norwich
- Portsmouth
- Reading
- Southend
- Southampton
- Watford[1]

United States (24)
- Atchinson, Kan.
- Cincinnati, Ohio
- Williamsburg, Pa.
- Columbus, Ohio
- Dennison, Texas
- Denver, Colo.[1]
- Fresno, Calif.
- Grand Junction, Colo.
- Kalamazoo, Mich.
- Knoxville, Tenn.
- Miami, Fla.
- Miami, Okla.
- Minneapolis, Minn.
- Mortevideo, Minn.
- New York, N.Y.[1, 2]
- Paterson, N.J.[1, 2]
- Pomona, Calif.
- Providence, R.I.
- Riverside, Calif.
- Sacramento, Calif.
- Stamford, Conn.
- Tulsa, Okla.
- Urbana, Ill.
- Washington, D.C.[1, 2]

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[1] Selective traffic ban (during certain hours of the day or exempting certain categories of vehicles).

[2] Temporary ban.

Source: Reproduced from Reference 215, pp. 44-45.

Pedestrian Areas. The degree of vehicular restraint in a pedestrian area varies from minor temporal restrictions to the total exclusion of private vehicles. In some cases, private vehicles are prohibited only for certain portions of the day. In many Yugoslavian towns, for instance, temporary traffic barriers are erected during the hours of the *corso*, "when it is customary for people to stroll in large numbers through the fashionable streets" (285, p. 10). A more formal scheme in effect on a portion of Oxford Street, a major shopping street in London, England, bans private vehicles Monday through Saturday between the hours of 11 A.M. and 9 P.M. During this time, only buses, taxis, service vehicles, bicycles, and invalid vehicles are allowed to use the street. The street has not been paved over, though the sidewalks have been widened (286, p. 306, David Bayliss). Mr. Bayliss notes that in this case, "... intense congestion and a weak road structure does not allow extensive and complete pedestrianisation" (p. 308).

In Oldenburg, Germany (population 132,000), according to H. Neidhardt, the streets have been completely paved from building to building over an area 400 m × 700 m (.24 mi. × .42 mi.). Motor vehicles are allowed only for loading and unloading between 6 p.m. to 10 a.m. and 12:30 p.m. to 3 p.m., and they are limited to a speed of 9 mph (286, p. 317). A. E. Naylor describes how in Leeds, England (population 500,000), a pedestrian area a little more than one-tenth of a mile long has been created. Only service vehicles are allowed in this area, and even they are banned between 11:30 a.m. and 3:30 p.m. As in Oldenburg, the street has been "repaved as footway from wall to wall. Judicious use of seats, planting boxes, large litter receptacles, telephone booths, kiosks, bollards, trees and lighting create a narrow (16-ft.) lane through which vehicles can travel—but still on footway flagging. As a result, drivers (for a change) are intimidated and proceed very cautiously along these lanes, very often quietly following a pedestrian without as much as a 'beep' or a slip of the foot on the accelerator" (286, p. 320).

The Nicollet Transitway in Minneapolis, Minnesota, is an example of a pedestrian area in the United States which is reserved exclusively for the use of pedestrians and transit vehicles (27, p. 13). Reference 27, Auto-Free Zones: A Methodology for their Planning and Implementation, contains many other examples of pedestrian malls in the United States and Europe for the reader wishing further detailed individual descriptions.

Traffic Cells. The concept of traffic cells involves dividing an area into a number of zones, usually encircled by a ring road. Traffic is not restricted within each zone, but a zone can be entered from only one point on the surrounding ring road. Traffic between zones is banned, except for public transit, emergency vehicles, and sometimes taxis. The two major examples of cities which have divided their central areas into traffic cells are Bremen, Germany, and Gothenburg, Sweden.

In 1960, the historical city center of Bremen, an area approximately .6 mile long and .4 mile wide, was divided into four traffic cells. The two streets which form the boundaries are reserved for the use of buses and trams. Pedestrian areas were created in portions of each cell, and the remaining streets were converted to one-way flow (215, p. 42).

The program in Gothenburg, Sweden, population 444,000 is better known, though it was instituted 10 years later than the one in Bremen. In Gothenburg, the central city, an area about .25 by .5 mi. bordering the Göta River, is divided into 5 zones; only public transport vehicles are allowed to move between the zones. Figure 3-2 is a schematic representation of the plan which also indicates changes in traffic volumes along major arterials following implementation of the scheme. Taxi drivers have complained of the restrictions and are experimentally being permitted to use a transitway connection between two of the cells. It is planned eventually to divide the entire central area of Gothenburg into traffic cells, which would involve an area six times as large as the area presently involved (286, pp. 314-316, Curt M. Elmberg). The total cost of the present program is reported to be $200,000, including the cost of an extensive public information program, setting up traffic barriers, relocating tram stops, painting zone borderlines and transit routes on streets, erecting signs, and enlarging and improving the peripheral streets to make sure they can handle the diverted traffic (124, p. 50). Liverpool, England, is reportedly planning a version of this method using two traffic cells (285, p. 9).

Size of Zones. Almost all vehicle-free zones to date have involved rather small areas, often only several blocks of a major shopping street, and it is not known whether the concept would be feasible in much larger areas. C. Kenneth Orski, author of an important article on the subject, points out that "it is probably no accident that existing pedestrian precincts seldom exceed 400 to 500 m in length [440 to 550 yards]. This may be the distance it is felt an average shopper is willing to negotiate on foot. Beyond that, some mechanized circulation system may be necessary" (215, p. 40). Many pedestrian areas already provide special mini-buses, pedestrian-trains, or other forms of public transit as discussed in more detail below.

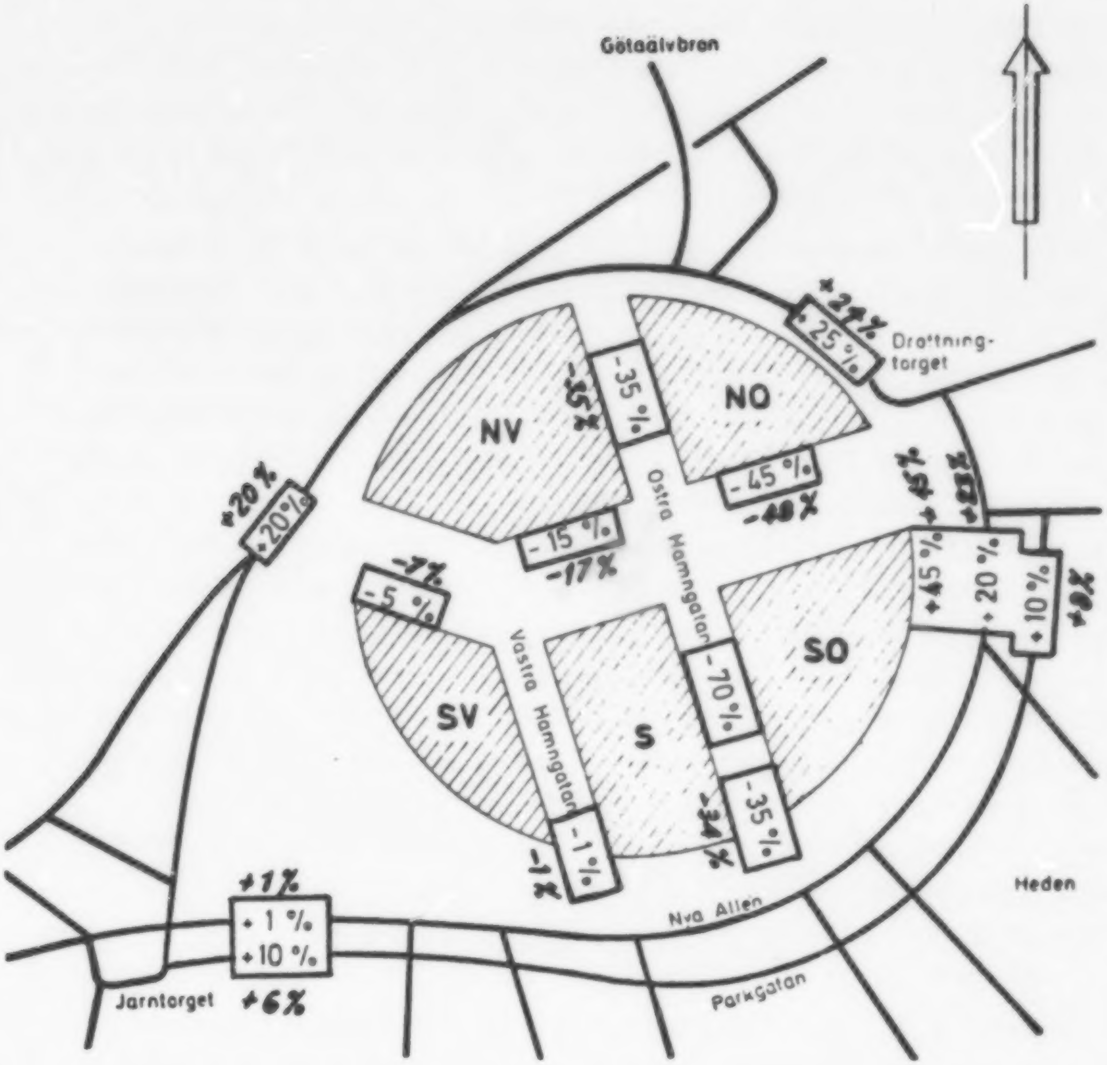

Figure 3-2. Schematic representation of Gothenburg, Sweden traffic restraint system.

NOTE: Hatched areas are quadrants; lines represent major arterials. Numbers refer to percentage change in vehicle volumes along central area routes two weeks and eight weeks (figures in boxes) following introduction of scheme in August 18, 1970.

SOURCE: Curt M. Elmberg, "The Gothenburg Traffic Restraint Scheme" (Paris: Organization for Economic Cooperation and Development, May 1971), p. 22.

Reproduced from 133, p. 4-6.

Large-scale projects must find ways of dealing with the problem of fringe parking, goods delivery, traffic rerouting, transit service and internal circulation. J.M. Thomson, another important authority on traffic restraint, notes that "the need for vehicular access appears to impose a fairly severe limit on the size of these areas, because the larger they are, the larger is the volume of exempt traffic having to pass through the periphery to reach the inner parts" (285, p. 11). He also cautions that even if a large vehicle-free zone were provided with public transportation, this service would not adequately meet the transportation needs of special groups such as doctors, invalids, salesmen and government officials (285, p. 11). Another source notes that "long-term planning for adequate, efficient transportation and goods movement could make larger vehicle-free areas more realistic; however, the capital investment would be major and would require a major reassessment of community priorities" (6, p. A-31).

To limit traffic in large areas, the technique of traffic cells would probably be more applicable than the complete prohibition of private vehicles, though the city of Florence, Italy, has banned automobiles from a 40-block area in its historic center, apparently successfully (215, p. 41). Gothenburg, Sweden, is planning to enlarge its system of traffic cells to cover an area 6 times as large, and large-scale projects are in the planning stages in several other cities as well. In Vienna, creation of an "environmental oasis" 1.2 km (about .7 mi.) in diameter which includes the historic city center is being contemplated, and New York City's proposed Madison Mall would extend for 15 blocks or nearly 2 miles along Madison Avenue, making it the longest pedestrian street in the world (215, p. 41).

Mr. Orski suggests creation of a large vehicle-free zone as a means of recreating a leisure-oriented downtown area free of high density business activity.

> "Most affected by the traffic ban would be large-scale business and commercial activities, whose relocation to more outlying places in the metropolitan area could be beneficial in any event. The inner city would gradually resume its original role of fulfilling the needs of people in search of amusement, entertainment, and relaxation and of providing a place where visitors and residents alike can shop, visit museums, or simply sit at a sidewalk cafe watching the world go by.

> Viewed in this light, automobile bans cease to have the negative connotation that some would ascribe to them and become a positive instrument for desirable urban change.
>
> "At least one city has embraced this point of view. The master plan of Rome envisages shifting major business, administrative, and commercial activity from its present location in the old city to a new center, leaving the classical center to services, hotels, boutiques, tourism, etc. Future traffic restraints in the old city are viewed as a means of discouraging the location of further business activity in the historic center of the city."

Social and Economic Effects. A crucial question that is often raised in connection with vehicle-free zones is what effect they will have on business in the area. Many shopkeepers are often initially opposed to the creation of such zones, but they usually become ardent supporters after the zones have been implemented, since business activity within the zone usually shows an increase. For this reason, it is not uncommon for groups of shopowners in a city where a pedestrian zone has been implemented to petition for an extension of the zone to include their area. In Oldenburg, Germany, for example, after a pedestrian mall was created, turnover in retail stores was reported to be above average, and the shopkeepers in the area were so pleased with the project that they offered to pay for construction of a multistory parking garage on the fringe of the town center (there were already four garages around the edge of the pedestrian area), 286, p. 317. In Bremen, Germany, 10 years after the system of traffic cells was initiated business in the CBD is prospering: "severe vehicle restrictions have failed over a long run to affect adversely the center city's development or to promote its decentralization" (215, p. 42).

Applicability. One of the most important considerations in evaluating a proposed traffic restraint area is the overall adequacy of the road network to handle traffic that would be diverted from or rerouted around a vehicle-free zone. Mr. A.T. Morris suggests that "the towns in England which have greatest chances of success in applying [traffic] restraint are those which have, already, invested substantially in major relief road construction." If displaced traffic creates congestion problems in the surrounding areas, the operation of public transit vehicles could be hampered, which might seriously threaten access to the pedestrian zone (286, p. 313). This has in fact already occurred in Leeds, England, where diversion of traffic from a newly created pedestrian area "put a strain on road capacity elsewhere in the centre and considerable delays were experienced by Public Transport" (286, p. 320).

Restricted or vehicle-free zones have been implemented in cities of all sizes. In terms of having a substantial impact on traffic conditions and air quality, however, they may be most suitable in small or medium-sized cities. "In Paris, for instance, a dozen separate areas would be needed to give relatively the same effect as one area in Bonn or The Hague" (285, p. 11). In addition, smaller cities which have implemented traffic cells have often been able to divert traffic to an already existing inner ring road. Few American cities have ring roads, and while it might be feasible to construct one in a small or medium-sized city, building an inner ring road to support a traffic cell scheme would be costly and disruptive in a large, older city, where almost all land is heavily built up. Most pedestrian areas also include provisions for additional fringe parking facilities near the ring road which, again, might be expensive and difficult to construct in the downtown areas of large cities.

Climate also plays a role in determining where pedestrianized areas are appropriate. For example, they may not be considered practical in regions with very cold winters or hot and humid summers, though vehicle-free zones are now in existence in cities which experience extremes of hot and cold such as Minneapolis, New York City, many Scandinavian cities, Miami, Florida, and Rome, Italy.

All traffic cell systems and the majority of pedestrian areas have been instituted in European cities where population densities are higher than in U.S. cities and people are generally more accustomed to walking, bicycling, and using public transit than are most Americans. Whether large numbers of Americans would learn to use these modes is still undetermined.

Mr. Orski concludes his article on restricted and vehicle-free zones with some thoughts about factors that should be considered before establishing a system of traffic limitations (215, pp. 43-43):

> "Available experience shows that traffic bans are operationally feasible and commercially successful. The degree to which they can be implemented will vary widely in different cities depending on such critical factors as the geography and climate of the city; the size, character, and function of the central area; the availability of public transport; the shape of the urban road network; the urgency of the local air pollution problem; and—not the least—people's propensity to walk. It will also depend on the local attitudes and the goals the given city hopes to achieve: A city that actively seeks to preserve a

> healthy, economically viable center is likely to adopt a different strategy from one that tolerates or wishes to encourage the dispersal of activities to the suburbs.
>
> "Total vehicle exclusion is likely to find the widest scope for application in the central districts of small and medium-sized towns, especially ones of historic character, with streets largely devoted to retail commerce. However, even in larger and newer, more automobile-oriented cities whose central districts contain a mix of business, commercial and service activities, there may be considerable room for trade-offs between accessibility and environmental quality."

Complementary Strategies. Provisions for adequate transit service should be an integral part of planning for any restricted or vehicle-free zone. Transit service in such zones is important in two ways: to provide transportation for those people who are diverted from their cars, especially in the case of a traffic cell scheme, and to provide internal circulation for medium-and large-sized pedestrian areas. Rather than simply instituting severe traffic restraints, the emphasis should be on "constructive discouragement of individual motorised traffic in favour of public transport" (286, p. 318). As Fenton Jordan puts it: "You have got to make riding downtown in some form of public transportation so much more attractive or cheaper that you would lose your desire to bring your car downtown" (112, p. 22).

Most cities that implement restricted or vehicle-free zones do so in conjunction with providing some form of improved public transport. A good example of this is the city of Nottingham, England, which is in the process of implementing a wide-ranging program of traffic restraints. Mr. F. Higgins of Nottingham states: "It is our view that increased public transport facilities must be provided before placing restrictions on the use of cars" (286, p. 306). With this in mind, the Nottingham City Council is planning a comprehensive program to upgrade transit service by providing more frequent bus service, installing bus shelters with informational displays, building a new public transport information center in the downtown area, and installing an improved fare collection system as well as bus monitoring equipment to increase service reliability. The council plans to provide a subsidy for the cost of these improvements so that fares can be kept low. Within the central city, where through traffic is banned except for buses and emergency vehicles, a free bus runs at

5-minute intervals between bus stations, the shopping area, and off-street parking facilities. A park-and-ride service for Saturday shoppers has also been established, and has proven successful (ibid.).

Not only is public transport a necessary component of a restricted or vehicle-free zone, transit service itself may be improved by the institution of such a zone, unless, as in Leeds, England, it is hampered by congestion due to inadequate provisions for the rerouting of traffic. In Gothenburg, Sweden, one of the stated goals in initiating the system of traffic cells was "to increase the practicability, regularity and reliability of public transport" (286, p. 314). In Gothenburg, several tram routes and some city and regional bus routes run through the area which has been divided into traffic cells. It was hoped that reducing private vehicle travel would allow transit vehicles to operate faster; however, on the transit routes affected, there was no noticeable reduction in travel time. This is explained by the fact that only 5 percent of a route is in the central area, and any gains in speed on this portion of the trip do not noticeably affect overall trip time.

Gothenburg was the only city INTERPLAN discovered which had measured the effect of a vehicle-restricted zone on transit ridership. It was found that there were 6 percent more transit trips to the CBD on weekdays after the traffic cells were implemented, and 2 percent more transit trips on Saturdays. Polls revealed that people switched to transit not because of the traffic cells themselves, but because of problems with parking, i.e., if they were unable to find a parking space in the cell they originally entered, they were forced to drive all the way to the perimeter, get on the ring road, and drive into another cell (286, p. 315).

Other strategies which could be implemented in conjunction with restricted or vehicle-free zones are: controlling the supply (3.3.2) or price (3.2.2) of parking available; constructing fringe parking lots (1.2.3); and making traffic flow improvements (2.1.2) to improve conditions on the streets that remain available to private vehicles.

IMPACTS ON GOALS

Congestion. The creation of a pedestrian mall obviously eliminates congestion on the streets included in the mall. Congestion in the surrounding area, however, is usually increased to some extent, as traffic is forced to bypass the restricted zone. Measurements of the effect of a vehicle-free zone on traffic conditions were taken in London after the Oxford Street pedestrian area was implemented. The results can be summarized as follows (286, p. 308):

- The average trip time for private vehicles passing through the area rose from 4.6 to 5.3 minutes (15 percent).
- Average speed in the area decreased from 8 mph before the experiment to 6.5 mph after traffic flows once again stabilized.
- Vehicle flows on parallel streets rose from 700 to 800 vehicles/hour, while average speed dropped from 8.5 to 7.8 mph.
- Traffic flow patterns on adjacent parallel streets leveled out to form a plateau from 9:30 A.M. to 5:30 P.M., in contrast to the previous more acute rush-hour peaks.
- On Oxford Street itself, vehicle headways rose from 2.7 to 9.4 seconds.

It should be remembered that this project was not undertaken to improve traffic conditions, but to improve the pedestrian environment, assist public transit buses, and reduce accidents (286, p. 308). From these standpoints it was judged successful, and it is being studied for wider application in London.

Traffic measurements taken in Gothenburg, Sweden, further illustrate the effects of traffic cells on congestion. Two months after the experiment was initiated, traffic flows had stabilized. Traffic on the main arterial was down 70 percent (see Figure 3-2 above), while the ring routes registered traffic increases of up to 25 percent at some points (286, p. 315). INTERPLAN found no statistics on whether total trips or VMT in the area decreased, increased, or remained the same. In any case, pedestrian areas are not designed to reduce VMT. In fact, they often aim to attract trips to the area, and additional parking facilities are usually added to handle the additional vehicles.

Air Quality and Energy Consumption. Dramatic reductions in air pollution have been recorded as a result of banning motor vehicles from certain urban areas.

- When Tokyo banned cars from 122 of its busiest streets on Sundays, which is the busiest shopping day in Japan, air pollution levels were cut in half (7, p. 3-31).
- When Madison Avenue in New York was closed to traffic in the spring of 1971, CO concentration levels dropped from 22 ppm to 8 ppm (215, p. 37).
- A ban on private cars in the central area of Vienna lowered CO levels by 54 percent (215, p. 37).

- "The city of Marseilles [France] conducted a series of experiments in October of 1971 to determine the air quality effects of motor vehicle restraints. One scheme involved prohibiting all private cars from entering the central area for a period of ten days. Nine kilometers [5.4 miles] of exclusive bus lanes were added to existing service, and on one day, all public transportation was free" (3, p. 7). The results of this experiment are shown in Table 3-13.
- On the main shopping street in Gothenburg, Sweden, where traffic was decreased 70 percent as a result of the creation of traffic cells, the 30-minute CO concentration dropped from 60 ppm to 5 ppm (286, pp. 315-316). As an incidental benefit, shopkeepers reported that they only needed to clean their windows once a week, instead of once a day as they had before the institution of the traffic cells.

Table 3-13. Reductions in CO levels in central Marseilles' auto-free zone.

Sampling Station	ppm of CO		Remarks
	before	after	
Banque Italienne	19.3	3.9	average of 7 readings/day at each location (8 a.m. - 6 p.m.)
Dames de France	19.4	2.8	
Magasin General	17.5	3.8	
Belle Jardiniere	18.9	4.0	
mean value	18.8	3.6	

Time	ppm of CO		Remarks
	before	after	
8 a.m.	20.2	5.5	average of readings at four locations
10 a.m.	19.8	3.3	
12 noon	14.7	3.6	
2 p.m.	14.2	2.7	
4 p.m.	19.8	3.3	
5 p.m.	20.3	3.9	
6 p.m.	22.3	4.1	

Before: September 13 - October 6, 1971
Total of 1,138 samples taken at 2-hour intervals

After: October 7 - 16, 1971 (ban on private cars; buses and taxis allowed).
Total of 496 samples taken at 2-hour intervals

Source: Association pour la Prevention de la Pollution Atmospherique, Comite Marseille-Provence, as cited in Organization for Cooperation and Economic Development "Reducing Motor Vehicle Emissions through Traffic Controls and Transportation Policies" (Working draft), 1971.

Source: Reproduced from Reference 94, p. III-32.

As encouraging as these figures appear, however, they do not tell the whole story. While pollution levels dropped on the streets where traffic was banned, in some cases they rose in the surrounding area because of increased congestion. Thus, closing Fifth Avenue in New York City to traffic in the summer of 1970 reduced CO levels on streets closed to traffic from 30 ppm to 5 ppm, but CO levels were increased on adjacent streets which carried the diverted traffic, and "when an auto ban was implemented in a section in Rome, disastrous traffic jams and air pollution were created all around it" (7, p. 3-31).

Again, Mr. Orski's comments on the phenomena of air pollution and smog formation and the potential of vehicle-free zones for alleviating this problem are worth repeating (215, p. 38):

> "However, car-free zones are not by themselves a complete answer to the vehicular air-pollution problem. Air quality in the city is influenced by two separate phenomena: the street-level pollution, high in concentration but localized in nature, and the less concentrated but more widespread pollution consisting of a mixture of vehicular exhausts and pollutants from stationary sources that in certain circumstances build up as a blanket over the city and, in the presence of sunlight, produce secondary photochemical products known as oxidants (smog).
>
> "Exclusion of vehicles effectively reduces street-level concentrations of pollutants, particularly carbon monoxide, in the immediate area; it will contribute little to improving the overall urban air quality, which is a function of emissions from thousands of vehicles spread throughout the metropolitan area.
>
> "In most cities, however, airborne pollutants are subject to relatively rapid disperson and mixing and do not tend to build up as an envelope over the urban area; the main problem is how to reduce local pollutant concentrations in the street environment. In such cities, strategies involving auto-free zones and other measures tending to reduce vehicle activity in pollution-prone areas deserve careful attention as an alternative to source control."

Los Angeles is an example of an urban area where the establishment of a vehicle-free zone would probably have a very minor effect on air quality. If the Los Angeles CBD were converted to an auto-free zone as some propose, air quality in the immediate vicinity might improve, but the overall effect would be negligible, since only 3.1 percent of trip-ends in the South Coast

Air Basin are in the Los Angeles CBD, and it is estimated that overall VMT would only be reduced by 0.6 percent (6, p. A-29). Establishing a vehicle-free zone with fringe parking around the area would have very little effect on VMT and automotive emissions, since people would still have to drive most of the way and would only use transit for the short distance from the parking lot to the pedestrian area. Furthermore, "in the South Coast Air Basin, the higher readings for atmospheric pollutants are not recorded in the Los Angeles CBD or in other basin CBD's. In 1970, the highest carbon monoxide reading was recorded at Reseda (one hour average, 54 PPM); the highest oxidant reading which averaged 0.67 PPM, was recorded in Upland. These are both suburban-type communities" (106, pp. 68-69).

Only one source (6) mentions possible energy savings from the establishment of restricted or vehicle-free zones. This source estimates that auto-free or traffic-limited zones could result in a regional energy reduction of 0.5 to 2.5 percent (p. 17). This report indicates that such savings would be due to a reduction in stop-and-go driving rather than to a reduction in VMT.

OVERALL EVALUATION. INTERPLAN's evaluation of restricted or vehicle-free zones is summarized below.

- Traffic cells and vehicle-free zones have been proven to be useful measures for eliminating or reducing localized congestion and air pollution, but they have no significant impact on air pollution and energy consumption unless implemented over much larger areas than any to date. Centers of traffic congestion and air pollution concentration might be shifted somewhat by the implementation of such zones, but this would probably have little effect on these problems citywide, unless, again, the area affected was very large. Freeway rush-hour congestion would not be affected at all unless a large center city vehicle-free zone were to increase decentralization of work locations, thereby tending to disperse heavy work flows away from the CBD.
- This is not a short-term action. Any attempt to create traffic cells or a pedestrian area would require considerable planning to work out the many details involved, such as rerouting of traffic in the area, providing more parking facilities, improving public transit service, etc. Even the comparatively small Gothenburg project required 7 years of planning (124, p. 50).
- Most experience with this concept has been in European cities, which differ in some important respects from American cities. It is still uncertain whether European experience would be applicable to most U.S. cities.

- Systems of traffic cells such as the ones in Bremen and Gothenburg probably have more potential for reducing VMT and encouraging use of transit than do pedestrian areas.
- There are better reasons for implementing pedestrian areas than attempting to improve urban traffic conditions or air quality, including the desire to improve business or to preserve an historic area.
- There seem to be no major drawbacks to this strategy, unless restricted or vehicle-free zones were to be hastily implemented without adequate consideration and planning and provision of additional required transportation facilities.
- While implementing vehicle-free or restricted zones should probably not be considered as a primary action, it could be useful as a supplementary action in connection with such strategies as traffic flow improvements (2.1.2), or encouraging walking and biking (1.4) and the use of public transit (1.2).

Limit Parking Spaces (3.3.2)

While manipulating parking costs (3.2.2) creates an economic disincentive, limiting parking spaces (3.3.2) is an action directed at restricting supply. These two actions share one purpose: to discourage driving into the city, thereby reducing traffic on city streets and on roads approaching the city. When parking is limited, traffic will be diverted either to other (suburban) locations, where parking is known to be in unrestricted supply, or to other means of travel to the downtown destination, such as transit or para-transit. Manipulating parking charges has the advantage that it raises revenue for improving auto alternatives; limiting parking spaces has the advantage that it is more direct and its effects do not depend on consumer's decisions. These two actions are probably most effective when used together, and in combination with efforts to increase transit capacity (1.1), attract transit ridership (1.2), and improve traffic flow through traffic control (2.1.2).

EXPERIENCE. There are a great many more proposals and plans for limiting parking than there is actual experience, but what little experience there is seems to support the effectiveness of this technique. Measures to limit parking may deal with one or several of the five types of on- and off-street parking facilities usually available in a city (see p. 3-33). Nearly every city in some way controls on-street parking on most commercial and some residential streets by banning parking during rush hours and limiting the length of time one car may stand parked. Municipalities may also have direct control over municipal parking lots for shoppers and government employees. But most parking is in privately owned residential, business and commercial lots, which have traditionally been unregulated in the U.S. Many of these lots are not even for public use but provide space at no charge to employees or other special groups.

Only three examples of the effect of restricting parking have been found by INTERPLAN. The city of London, England, has had the longest experience with parking controls, since the agency responsible for city and transportation planning, the Greater London Council, has authority to license public off-street carparks (containing 30 percent of total nonresidential spaces) and to restrict additional public carparks. The number of spaces in central London was deliberately reduced between 1966 to 1971 from 125,000 to 105,000, or 16 percent; the number of cars using these spaces decreased by less, due to an increase in the peak occupancy rate from 76 to 85 percent (Bayliss, D., "Parking Control for Restraint in Greater London," in Reference 213, pp. 86-90). Nonetheless, this decrease in available parking is given joint credit with traffic management measures for the roughly 20 percent increase in both peak and off-peak travel speeds in Greater London since the mid-'60s. Another European city which has tried parking controls is Marseilles, which observed about a 40 percent decrease in CO concentrations in the center city during 10 days when there was a ban on parking (3, p. 10). The CO reduction was believed to be due more to reductions in the number of vehicles than to increases in speed of autos passing through the area.

The only instance of parking restrictions in the U.S. which INTERPLAN found was on the occasion of a three-day strike of parking garage operators in Pittsburgh in August 1972 (241, pp. 6-8). The strike closed more than 90 percent of the central business district's parking places, and most spaces in fringe areas. As a result of the strike, motorists reduced their auto trips to the CBD by 25 percent and rode public transit instead. The local transit carrier, Port Authority of Allegheny County, experienced an increase in ridership of 12 percent during the strike (170, p. 40). There was also increased use of carpooling and of parking at outlying suburban lots. The transit system proved that it was capable of handling the sudden increase in ridership smoothly. But, in spite of the fact that the new transit riders reacted favorably to the service there was no net gain in public transit ridership after the strike. People simply went back to their automobiles as soon as facilities for them were again made available, but the fact remains that their needs were fulfilled by transit when parking was unavailable and traffic downtown was reduced to weekend levels.

Despite the lack of concrete evidence for the impact of parking limitations, this policy has often been proposed in recent years as a means of reducing urban congestion and air pollution. Typically, proposals directed at reducing congestion aim at discouraging commuter parking downtown but provide off-street space there for shoppers and other short-term parkers. The Nottingham, England, transportation plan, for example, includes restriction of on-street parking downtown and experimentation with closing of two of the most heavily used parking lots between 7:30 a.m. and 9:30 a.m. so they cannot be used by commuters (286, p. 306). In Leeds, England, the city intends to provide commuter parking space around the fringe of the city near the ring road (beltway) and connect it to the downtown area with a minibus shuttle. Space for shoppers and short-term parkers would be provided in garages around the central core of shops, sometimes in the same building with a shopping complex (286, p. 319).

A more innovative suggestion has been proposed by M. J. Bruton in the Journal of the Institution of Highway Engineers (34). While most proposals are concerned, understandably, with policy affecting municipally controlled parking space and possibly with the licensing of new lots, Mr. Bruton suggests that currently existing private parking could be limited by creating an economic incentive for parking lot owners to convert these lots to some other use. City ordinances would be revised so that within a given area where a parking policy is to be put into effect, "all space capable of being used for parking should be valued, and a rate charged equivalent to the market rate for letting that space for car parking, regardless of whether the space is actually used for that purpose." Owners who arranged their available space in such a way that it could not possibly be used for parking could claim an exemption to the fee (34, p. 9). If employers felt that they might lose employees or might not be able to attract new ones because of such parking restrictions, they might consider subsidizing their employees' use of public transit or providing car, van or buspools for their employees.

Most proposals directed at using parking policy to reduce congestion focus on discouraging the long-term or commuter parker rather than the shopper or other short-term parkers. The rationale behind this approach is that use of parking downtown should be maximized, i.e., turnover should be frequent during the day, and also that if space is to be limited, then shopping, personal business, restaurant, and entertainment trips should be favored, since the city benefits economically from these trips and they are most likely to be diverted to outlying commercial centers if parking becomes a problem. This approach has been questioned by Mr. Bruton, however, on the grounds that little trade will be lost to downtown merchants if short-term parking is scarce because their customers are largely captive anyway, and that transit companies will benefit if commuter parking is favored and short-term parking discouraged because this will tend to even out transit demand peaks during the day (34, pp. 10-12). He advocates the opposite policy from that usually suggested, that is, allocating most downtown parking spaces to commuters and leaving a minimum available for short-term parking. An additional benefit of this scheme, he claims, would be improvement of off-peak air quality; though peak-period air quality would not change or might be worse than if commuters were discouraged from driving downtown, he feels that "at the very least transport planners should aim to achieve reasonable environmental conditions during the off-peak periods" (p. 10). Though his proposal runs counter to the prevailing trend, it would be of interest to planners in cities who agree with his premises. Harry F. Orr, director of parking and transportation in Tampa, Florida, for example, agrees that trying to lure shoppers downtown by giving them preferential parking treatment is not the way to revitalize the inner city. He says, "I think what we have to concern ourselves with is the new concept of downtown which is basically financial, governmental, office, and maybe some cultural attractions. . . . the shops that will survive in downtown are those that have the captive audience which is working downtown." (112, p. 38).

In contrast with policies directed at reducing congestion, EPA's parking management proposals do not distinguish between types of parkers, although they do place a special burden on employers to see to it that their employees change their parking habits (see Manipulate Parking Costs, 3.2.2 above). Reduction of VMT by management of parking supply was included by EPA in the proposed control strategy plans for all five major California air quality regions and similar measures were also proposed for Boston, Philadelphia, Pittsburgh, the New Jersey suburbs of New York, the District of Columbia and its suburbs, Denver, Portland, Seattle, Spokane, Houston, Phoenix, Tucson, and Fairbanks (80, p. 31233, and Federal Register, Vol. 39, No. 164, 22 August 1974, p. 30440). The EPA originally proposed that the enforcement of local zoning or land-use laws requiring an employer to provide a given number of parking spaces for a given number of employees be restricted, and that new public and private parking facilities with more than 50 spaces be reviewed for their impact on air quality before construction. As an alternative to review of each new parking facility, EPA suggested that it could accept a five-year plan outlining local management of parking facilities, submitted by the local government (80, p. 3126). If the plan were accepted, EPA would no longer require one-by-one review of new facilities. These proposed regulations were later modified to exclude residential, church, and recreational parking and to raise the minimum parking facility size for review to 250 (Federal Register, Vo. 36, No. 237, 11 December 1973, p. 34125). Another EPA suggestion that spaces in public parking facilities be reduced by 20 percent was dropped due to strong adverse public reaction.

This group of measures, in combination with parking surcharges (see Manipulate Parking Costs, 3.2.2, above), was judged by EPA to be the only method capable of obtaining significant VMT reduction in regions of spread-out development, except for comprehensive restrictions on the sale of gasoline (Federal Register, Vol. 38, No. 237, 11 December 1973, p. 34124), and they were promulgated in December 1973. Shortly thereafter, however, the EPA Administrator amended them to reflect Congressional intent as expressed in the proposed Energy Emergency Act. Although the bill was never passed, the Administrator felt EPA's regulations should be changed because of the strong Congressional opposition to EPA-enforced parking controls expressed in the bill's draft. He, therefore, deferred review of new parking facilities to January 1975, and regulations requiring parking surcharges were withdrawn, although such surcharges might still be approved if a state submitted them of its own volition. The year's delay in implementing parking review would be used to "thoroughly reexamine current parking regulation" and to allow local governments to develop regionwide parking management plans which could remove the need for any EPA promulgation (Federal Register, Vol. 39, 15 January 1974, p. 1848). Procedures for demonstrating satisfactory compliance as well as proposed area-by-area regulations were published by EPA in August 1974 (Federal Register, Vol. 39, No. 164, 22 August 1974). At that time, Denver and Portland had already received EPA approval for their parking plans, and Seattle and Spokane were actively developing theirs.

The EPA would certainly welcome a reversal of cities' efforts to assure adequate parking downtown which have in the past been enforced by requiring new buildings to include parking facilities. The New York City Planning Commission set a precedent for such a reversal by refusing to approve the construction of several parking garages to provide short-term parking at reduced rates for business and shopping purposes in midtown Manhattan (133, citing Lyle C. Fitch and Associates, Urban Transportation and Public Policy [San Francisco: Chandler Publishing Company, 1964]). The reason cited was that these additional traffic generators would unduly further congest street traffic and might actually reduce the total volume of movement into and out of the midtown area. In England, the Glasgow Corporation is reported to be asking for a special parliamentary order which would require a private firm to obtain permission before providing five or more parking bays on its premises (34, p. 9).

IMPACTS ON GOALS. The London, Marseilles, and Pittsburgh experiences with parking restrictions described above clearly indicate that limiting parking can divert commuters to transit, contribute to freer vehicle flow, and reduce air pollution, *if* adequate transit service is provided, and *if* the local authority has sufficient jurisdiction to control a significant number of parking spaces. To briefly restate the experience, reducing available parking in central London over a period of 5 years while also implementing traffic management measures was felt to be responsible for a 20 percent increase in both peak and off-peak travel speeds in Greater London. In Marseilles, banning parking from the central area for 10 days resulted in about a 40 percent decrease in measured CO concentrations in the area of the ban. In Pittsburgh, where parking restriction occurred because of a strike and not due to public policy, auto trips into the CBD dropped by 25 percent, transit ridership increased by 12 percent, and no disruptive side effects were experienced. Drivers returned to their habitual mode of travel as soon as the strike was over. INTERPLAN found no estimates of implementation costs or of energy impacts though the latter would be expected to be positive if congestion and air pollution were reduced.

Some indication of the impact of parking limitations on travel and traffic may be inferred from a 1968 survey of motorists in central London, the results of which are shown in Table 3-14. When asked what they would do if it was impossible to find a parking space in central London, most motorists replied that they would use public transit, walk, or ride a bicycle (67 percent). One in eight (13 percent) said they would not make the trip at all. The responses of American motorists would undoubtedly be less favorable to transit because only a few U.S. cities could hope to offer as adequate a substitute for auto travel as London Transport's bus and underground service. But this survey does give us some idea of the potential extent of diversion from auto modes if auto alternatives were to be improved; even in London, one-sixth of the motorists would simply switch to taxi, which would have little beneficial effect on traffic, though it would free parking space. And nearly 5 percent did not feel that any of the alternatives to driving their car were realistic.

OVERALL EVALUATION. Given that restricting parking spaces appears to have at least some positive effect on the goals, the issue in most cities would therefore be whether the expected benefits would offset the disadvantages of implementing the policy, and whether other actions or strategies would not accomplish the same end with less inconvenience in a shorter time, or more effectively. The disadvantages of controlling parking supply include most of those applying to manipulating parking charges (see 3.2.2), plus the following: (1) in U.S. cities, local authorities may not have control over enough parking space to enforce parking limitations in a meaningful way, (2) by themselves, parking limitations would be difficult to justify to the general and business communities, (3) if authorities did gain the power and mandate to restrict parking, they would also have to control rates charged for remaining spaces in order to avoid profiteering, (4) there are enforcement problems with on-street parking bans, (5) the availability of nearby uncontrolled parking diminishes the effect of localized restrictions, and (6) road pricing or parking pricing could be applied more selectively. These limitations are briefly discussed below.

(1) It would be a difficult and controversial action for cities to gain control over all private parking spaces in the CBD, since such parking may represent 50 percent or more of available parking space in the CBD. If the authorities are restricted to limiting new parking, they would first have

Table 3-14. London motorists' reactions to proposed parking restraints by trip purpose.

	Percent of those questioned who, if it was impossible to find a parking space in central London:					
Trip Purpose	Would use public transport	Would take a taxi	Would walk or bicycle	Would not make journey	Believe car is essential*	TOTAL
Work	72	8	7	10	3	100
Employer's business	51	21	4	17	7	100
Personal business	57	20	4	15	4	100
Shop	59	14	7	19	1	100
Meal, visit friends	58	20	5	15	2	100
Entertainment	62	21	2	14	1	100
Return home	50	21	14	6	9	100
More than one purpose	64	18	5	11	2	100
All purposes	62	16	5	13	4	100

*Respondent could not view the given alternatives as realistic.

Source: J. M. Thomson, "Some Characteristics of Motorists in Central London," Greater London Paper No. 13, The London School of Economics and Political Science (London, 1968), cited in Reference 170, p. 39.

to convince the public that the policy of requiring new buildings to provide parking should be reversed. The fact that such a policy would have little effect on available parking for some time might make it easier to convince the public, but by the same token, the long-term nature of this policy implies that benefits would not be seen for some years.

(2) Proposals to restrict either public or private parking spaces would be strongly opposed by some drivers and most businessmen. Reference 124 notes that it would be hard to justify a stringent program of parking controls on the basis of air pollution reduction "because nobody will be aware of a 25 percent [for example] reduction in air pollution. . . . If you are going to sell something that is politically unpopular to people and that will not make any difference that they can observe, you are going to have the whole program backfire" (pp. 57-58).

(3) Limiting public parking spaces may allow owners of private parking facilities to raise their rates and make excessive profits.

(4) Where there is a ban on on-street parking, the fine for violating it, multiplied by the risk of being fined, becomes the effective cost of parking. Some people will prefer this cost to the inconvenience of finding an alternative. In London, the infringement rate is about one-third, even with a force of 700 wardens in the central area (Bayliss, 213, p. 88).

(5) If the area of controlled parking is not large enough or has "holes" in it where parking is available, people will simply park outside the controlled area and walk in. Bayliss maintains that in city centers, the control area must extend one-third of a mile beyond the center of activity (Bayliss, 213, p. 88).

(6) Limiting the amount of parking is not as effective as road pricing or parking pricing policies in reducing VMT and air pollution. It cannot be "fine-tuned" as easily to selectively limit traffic by particular areas or times of day, and it cannot as easily be applied universally. Reference 133 predicts that "no parking program of regulation would be anywhere near 100 percent effective, while a comprehensive parking space tax might reach 85-90 percent of all off-street spaces" (p. 6-25).

The major argument in favor of retaining a policy of parking space control despite its limitations would be that, like manipulating parking charges, it is an important component of a multi-action package including improved transit service and traffic flow improvements. The importance of combining parking control, parking rates, and measures to encourage mass transit usage is explicitly recognized in EPA's procedures for determining the consistency with its goals of a region's parking management plan (Federal Register, Vol. 39, No. 164, 22 August 1974, p. 30461). INTERPLAN suggests that traffic flow improvements, which are directed primarily at reducing congestion, should also be considered in conjunction with parking controls, since without some form of traffic restraints, measures to improve traffic flow would have only short-term benefits because new traffic induced by the improved flow would eventually absorb any short-term gains (see Initiate Traffic Control Improvements, 2.1.2). Therefore parking space limitations should, like manipulating parking charges, be seen as reinforcing or supporting rather than leading or key actions.

SECTION 4

REDUCED URBAN TRAVEL DEMAND (4.0)

INTRODUCTION

The three previous sections have evaluated ways of manipulating existing travel demand by offering alternatives to auto (1.0), improving traffic flow on existing roads and building new ones (2.0) and discouraging travel by price increases or physical barriers (3.0). Some analysts have also explored the long-term approaches to reducing the demand for travel itself as a means of counteracting the ill effects of present travel patterns and modal choice. These approaches are the substitution of communications for travel (4.1) and the encouragement of decentralized land-use patterns (4.2), which are the subjects of this section. These two strategies at first glance appear to be distinct from one another and certainly involve different disciplines. However, the decentralization of land use patterns in a way which would reduce travel demand depends to some extent on the adoption of communications as a travel substitute, and the effectiveness of communications as a travel substitute depends on the extent to which it can facilitate dispersal of land use.

Because of this interdependence, a single table (Table 4-1) is used to document the evidence for these strategies' impacts, and the discussion of them in this section is organized in terms of action pairs, one from each strategy, which could be expected to complement each other. In INTERPLAN's view, in other words, there is little point in discussing either strategy separately; the two must go hand-in-hand if any of the predicted benefits are to have any chance of materializing. The exceptions which prove the rule are home communications centers (4.1.3) and increasing CBD residential facilities (4.2.3). Home communications centers are presently all that is needed to permit some types of work to be carried out from home; installation of such a center would, in itself, accomplish both travel substitution and a decentralization from the central office to a private home. Once such communications systems become available, they could be placed in any home where space permitted. Increasing CBD residential facilities would automatically offer some center city employees the option of moving closer to their jobs, and they would obviously not require any communications aids to reduce their need for travel.

INTERPLAN's recently released report (140) documents the state of the art of the two strategies and estimates their short-and long-range effects on travel demand, gasoline consumption, and users' transportation expenditures (see Table 4-1). A number of important recent documents have come to INTERPLAN's attention since the initial document search for the study which shed further light on the strategies' implications for travel demand, energy use, urban transportation costs, and transit use (72, 111, 152, 208, 274). The discussion which follows, while it therefore draws on INTERPLAN's own recent study, emphasizes the most recent insights gained from our continuing interest in this subject.

Table 4-1. Documented impact of strategies and actions on offsetting phenomena: Encourage Communications Substitutes for Travel (4.1), Encourage Decentralized Land Use Patterns (4.2).

PHENOMENA						COST ESTIMATES	
1.0 Improved Auto Alternatives	2.0 Improved Vehicular Flow	3.0 Reduced Urban Auto Use	4.0 Reduced Urban Travel Demand	5.0 Reduced Vehicular Air Pollutant Emissions	6.0 Reduced Vehicular Petroleum Consumption	Highway, Auto	Rail, Bus & Para-Transit
Reference 140 Not mentioned.	Noticeable improvement for commuters; no figures.	3% reduction in overall demand in short range (36 x 10^6 VMT), 14% in long range (168 x 10^6 VMT).		Positive effect; no figures.	3 million gals./day in short run; 20 million gals./day in long run.	Auto cost savings to consumers (@ 10¢/mile) of $1.25 billion annually in short run; $6-7 billion in long run.	Not mentioned.
Reference 72 Transit patronage could decrease because further urban decentralization will undermine heavy radial corridor flows which transit most efficiently carries.	Will be reduced to the extent vehicular use and travel demand are reduced; no figures.	No figures.	No figures.	Will be reduced to the extent vehicular use and travel demand are reduced; no figures.	Communications and the production of its hardware requires less energy than travel. Picturephone is 2.7 - 8 times more energy efficient than air travel between LA and NY. However, decentralization encouraged by communications could decrease efficiency of energy use.	Transportation savings not calculated.	
Reference 152 Not mentioned.	Positive, not quantified.	22% of peak period auto work trips in SF Bay area susceptible to communications substitution. This trip group is about 20% of total traffic but accounts for most of congestion.		Not mentioned.	Positive, not quantified.	Cost issues not addressed.	

Table 4-1. (continued)

PHENOMENA						COST ESTIMATES	
1.0 Improved Auto Alternatives	2.0 Improved Vehicular Flow	3.0 Reduced Urban Auto Use	4.0 Reduced Urban Travel Demand	5.0 Reduced Vehicular Air Pollutant Emissions	6.0 Reduced Vehicular Petroleum Consumption	Highway, Auto	Rail, Bus & Para-Transit
Reference 111, pp. 505-517. Need for CBD-oriented rapid transit systems would be curtailed. Circumferential high-speed transit service linking urban satellite centers could attract adequate patronage if development centers on transit corridor.	Not discussed.	Not discussed.	Limited empirical data from several sources indicate that CBD workers typically commute twice as far as suburban workers, p. 334. Gravity model tests on hypothetical city similar to Detroit showed that CBD workers would commute 11 miles, vs 8 miles for those working in one of 4 suburban satellite centers, p. 490. With neighborhood centers using the "commuter shed split" concept, trip length can be reduced to any desired level. Fifty centers in the hypothetical city resulted in an average trip length of 2.3 miles.	Not discussed.	Commuting to jobs in 4 satellite centers served by a circumferential PRT beltway requires about 60% as much energy as commuting to a CBD served by rapid rail; jobs in neighborhood work centers require only 20% as much energy for commuters.	In a typical large city, employment is expected to grow by 50,000 jobs over the next 20 years. Two transportation alternatives are considered for 3 job location patterns (pp. 428, 477). (Capital costs (CC) in 1969 $'s; operating costs (OC) in 1970 $'s; M = million.)	
						Auto-highway only	Auto-highway plus rail or PRT
						If the employment growth occurs in the CBD:	
						Highway CC: $252 M 20-yr. auto OC: 320 M Total: $572 M	Rail CC: $412 M Highway CC: 139 M 20-yr. rail/ auto OC: 356 M Total: $907 M
						If it occurs in 4 satellite centers:	
						Highway CC: $ 60 M 20-yr. auto OC: 236 M Total: $296 M	PRT beltway CC: $110 M Highway CC: 27 M 20-yr. PRT/ auto OC: 180 M Total: $317 M
						If it occurs in 50 neighborhood centers with "commuter shed split":	
						Highway CC: $ 0 M 20-yr. auto OC: 68 M Total: $ 68 M	Not applicable; minibuses and car-pooling would work well, as neighbors have common workplaces.

Table 4-1. (continued)

PHENOMENA						COST ESTIMATES	
1.0 Improved Auto Alternatives	2.0 Improved Vehicular Flow	3.0 Reduced Urban Auto Use	4.0 Reduced Urban Travel Demand	5.0 Reduced Vehicular Air Pollutant Emissions	6.0 Reduced Vehicular Petroleum Consumption	Highway, Auto	Rail, Bus & Para-Transit
Reference 208 Not quantified. Demand for short-haul transit could increase with workers living closer to work. Transit system design will change from peak-hour centralized orientation to locally centered, fragmented service.	Not mentioned.	If commuter lives close enough to work (1-4 mi.) he will not use car but will walk, bike, or take transit.	Dispersing an insurance company's functions to 18 locations in LA reduces average commute distance from 11 to 3 mi. Doubling the number of locations doesn't reduce this figure much.	Not yet considered by study. Closely related to energy savings.	Operating energy costs for "telecommuter" amount to less than 5% of those associated with commuting by auto: $5-8/yr. vs $200-300, and about 10% of the energy cost of transit commuting. Estimates that if 10% of commuter population were converted to telecommunications, 150 billion kw/yr. nationally could be saved.	Marginal commuting costs in LA are about $1,100/yr./employee. Cost of telecommunication/employee: terminal - $300-400; line charges-$600; computer charges - $50-60; energy - $5; total - $955-1065. Savings/employee in differential rent: $700/year. Savings to company in wages to compensate for long commute: 20% for clerks. Total cost of installation for 18-node dispersal: $13 million. Also increases labor pool and reduces turnover (savings in recruitment and training costs).	Not mentioned.

ENCOURAGE COMMUNICATIONS SUBSTITUTES FOR TRAVEL (4.1) AND DECENTRALIZED LAND-USE PATTERNS (4.2)

Increase Use of Existing Communications Facilities (4.1.1); Develop New Towns (4.2.1); and Disperse Economic Activity to Smaller Urban Areas (4.2.4)

EXPERIENCE. In itself, increased use of existing communications facilities is likely either to have no effect on urban travel or to increase it. Historically this has been the case: trip lengths, miles traveled per person per year, and numbers of telephones, data links, and other communications and transportation use indices have increased in parallel over time, as if communications and travel were complementary goods and not competitive ones. Until recently, it had been thought that further advances in communications technology would be necessary to provide the full video kinetic image required to substitute for face-to-face meetings of the type common to office interaction, and thereby permit greater flexibility in the location of the participants. When such advances became available, it was assumed, then and only then could communications substitute for travel.

However, the first year's work of Fairfield University and Goldmark Communications on the New Rural Society Project of the U.S. Department of Housing and Urban Development, reported on in Ref. 77, as well as earlier work by the University of London Communications Studies Group (52, 53), has shown that presently available telephone-based, audio-only communications channels can handle many more inter- and intra-office communications needs than had been previously thought. High capacity audio-video channels, which are expensive and require more "room" than is now available in our communications networks to be used on a widespread scale, have been shown to be necessary for only about 20 percent of intraoffice contacts (53) or, according to another source, for management conferencing only (208).

The New Rural Society project has been studying different kinds of teleconferencing set-ups for carrying out verbal group communication through audio-only systems, which they expect will permit location of many types of industry in areas previously considered too far away from present centers of activity. These locations could include, as specified in the HUD project, smaller urban areas, rural areas, or new towns, often built at some distance from urban areas

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in order to offer a "country life" atmosphere but requiring longer commutes for residents.

IMPACT ON GOALS. Since creating new towns and spurring growth in smaller urban areas has not so far been regarded as a means of reducing travel, there is little evidence to support a conclusion about their effects on goals. What little evidence does exist seems to indicate that these actions would merely transfer travel, emissions and energy requirements out of urban areas. A U.S. Economic Development Administration study (274) cites the example of an Illinois county which gained a steel mill. While no increase in congestion is reported, 80 percent of the labor force lived outside the county and some commuted up to 40 miles to work. This phenomenon, which was also responsible for spreading the effects of industrial development over a large geographic area, preventing "massive and rapid urbanization", runs counter to the common wisdom that reducing vehicle miles traveled or shortening trips is required to reduce congestion. The simple fact that these trips are being made in an area where excess highway and street capacity exists, rather than being added to the already overloaded freeways of a large metro area, explains the apparent paradox. Similar work trip lengths have been experienced by some residents of British new towns who have been found to be commuting outside their town, despite its intended design as a "self-sufficient" community (218).

In these two cases, trips presumably have been transferred to less congested facilities, but travel itself in terms of VMT has increased. This action, therefore, promotes the reduction of urban travel demand by increasing total travel.

OVERALL EVALUATION. Considering that at present principal surface arterials and minor arterials in small urban areas are congested far less than those in urbanized areas (see 142, p. 27), and that freeways in small urban areas, while slightly less congested than those in urbanized areas, can more easily be avoided during peak hours, a policy of encouraging dispersal of economic activity to small urban areas and newly-created towns should indeed serve to decrease congestion and increase mobility in urban areas. The associated vehicle emissions are also then transferred to an area more likely already to be in compliance with the national ambient air quality standards. However, some increase in gasoline demand might be expected due to the above-mentioned likelihood that the work trip may be longer for those living in remotely-located new towns or in low-density rural areas.

Increase Use of Existing Communications Facilities (4.1.1); Develop Neighborhood Work Centers (4.1.2); and Foster Suburban Employment Opportunities (4.2.2)

EXPERIENCE. This combination of communications and land-use techniques is the one which has given rise to the two most interesting attempts to predict the future implications of communications substitution for travel (Harkness, 111, and Nilles, 208; see Table 4-1). Both authors have investigated the cost, energy, and transit use implications of dispersing work now performed in the CBD or other large activity centers to smaller, more numerous satellite centers. Harkness takes as his example a hypothetical city, modeled on Detroit, in which 50,000 jobs are presently located in the CBD and investigates the impact of adding 50,000 more jobs in the CBD or in various "alternative future" location patterns within the urban area. Nilles performs a similar modeling exercise to determine the effects of dispersing the departmental functions of a Los Angeles insurance company to 18 smaller locations in existing commercial centers closer to workers' residences. While these computer-tested scenarios require many simplifying assumptions and cannot be regarded as "experience" or even as evidence, the possibilities which they project of reaping substantial benefits in travel reduction, energy savings, and overall cost savings to the dispersing firm (Nilles) and to transportation budgets (Harkness) deserve to be tested in the "real world."

IMPACTS ON GOALS. Harkness' exercise shows that average commuting distance decreased roughly 20 percent, from 10.8 miles to 8.2 miles, when the 50,000 new jobs are located in 12 satellite centers instead of in the CBD, and to 2.3 miles when jobs are located in 50 neighborhood centers (111, pp. 422-426, 490). The difference in trip times was even greater: placing jobs in four satellite centers would result in trip times almost as short (7.7 vs 7.1 minutes) as complete dispersal of jobs (number of jobs in every zone equals the number of workers residing in that zone), and nearly half as short as if all new employment were located in the CBD (13.9 minutes) (p. 512). As Figure 4-1 shows, transportation capital and operating costs and energy cost would be drastically reduced over the CBD case for the cases where zonal population equals zonal employment (case 5) and where jobs are dispersed to 50 neighborhood centers (case 6), and considerably reduced for the 4- and 12-satellite patterns (cases 2, 3, and 4). (See Table 4-1, Ref. 111, cost columns for more detailed information.)

FIGURE 6.6.1-A

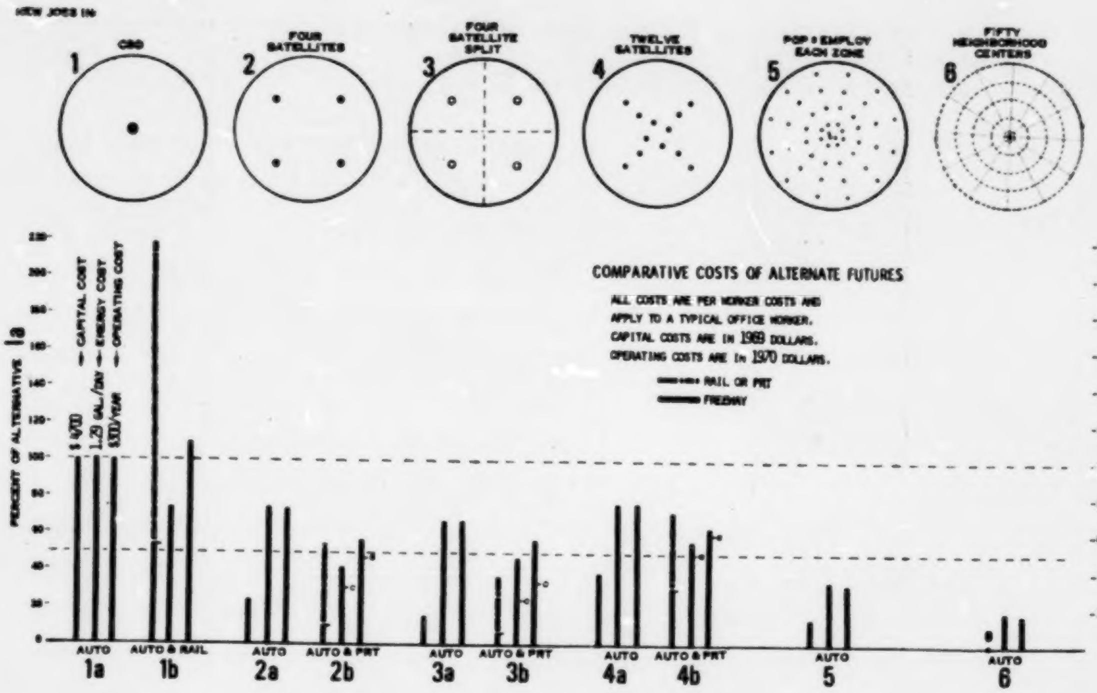

Figure 4-1. Comparative total transportation dollar and energy costs of locating new urban jobs in 6 alternative future urban patterns.

Explanation:

The circles at the top of the figure illustrate six patterns of new office employment. These patterns can be called "alternate futures" on the premise that urban planners and policy makers could mold new office employment into any one of these patterns, after first having decided which was best for the community. Alternative #1 is representative of the goals or plans currently adopted in many major cities. It calls for a relatively large growth in CBD office employment. The other cases represent sharp departures from this prevailing policy because they envision a no-growth CBD where all the office growth normally expected for the CBD would instead be located in satellite centers, dispersed job sites or neighborhood centers as shown.

The six main alternatives are further subdivided according to the mix of transport technology. This is indicated by the designations 1a and 1b at the bottom of the figure.

The three costs calculated are plotted as vertical bars in the figure. For ease of comparison, the costs of alternative 1a have been set at 100% and the other costs plotted as a percentage of the 1a costs. For example, the capital cost of alternative 1b is almost 220% of alternative 1a. The actual per worker costs are indicated on the figure only for alternative 1a. The capital cost bars are subdivided to show the portion of cost associated with freeways vs rail or PRT transit.

SOURCE: Reference 111, p. 480.

While Harkness' example does not specifically require new uses of communications in order to realize the benefits of a dispersion to satellite or suburban centers,* the more extreme forms of dispersal would require decentralization of organizations by "commuter shed split", a concept originated by Harkness which would only be feasible with a widespread teleconferencing capability. Commuter shed split would require participating firms to lease office space at various widely scattered points throughout the urban area and allow their employees to work at the one closest to home (111, p. 506). His cost analysis of the alternatives he models enables him to state that within the context of his example, the capital cost of placing jobs downtown and serving them with rail is $10,300 per worker, whereas placing them in four satellite centers and using freeways would cost $1,100. "Thus society could afford to spend up to $9,200 per worker to implement the satellite center concept," he concludes. "Put another way, society could spend $4,600 per worker on telecom or other measures necessary to implement satellite centers and still save $4,600 in transport capital costs." (111, p. 487) As Harkness goes on to point out, these potential tradeoffs and savings are even more impressive when 50,000 workers are involved (as in his example) and the savings are projected over 20 years, as shown in Figure 4-2. "[The figure] shows that the 20-year cost of alternative 1b [CBD-located jobs, both auto and rail systems] is almost $900 million 1969 dollars, whereas alternative 2b [four satellite centers with PRT] would cost about $300 million. Society could therefore afford to spend $100 million on telecom or other measures while saving $500 million on transport." (111, p. 487) The more extreme forms of decentralization which would require widespread teleconferencing would, in Harkness' example, make even more impressive savings possible.

Harkness is careful to point out that many other factors affect the decision to decentralize expected CBD growth and that the potential transport and energy savings "are not sufficient basis for advocating decentralization." (111, p. 487) But his findings lend support to the view that dispersal of workplaces to smaller centers within the metropolitan area can result in shorter commutes, requiring less gas and generating fewer emissions, while

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*"...the ability to maintain contacts electronically will reduce the need for offices to cluster in the CBD and will, therefore, *cause or allow* offices to decentralize to suburban locations..." [italics added] (111, p. 505).

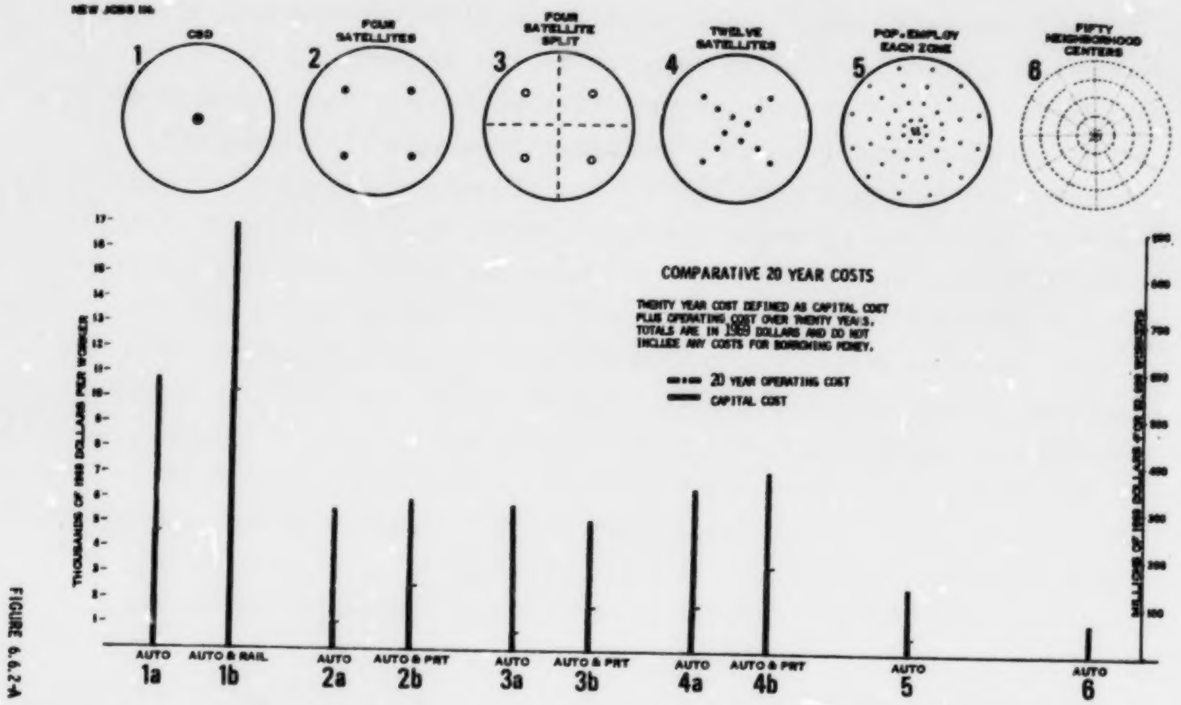


Figure 4-2. Comparative 20-year per worker transportation costs of locating new urban jobs in 6 alternative future urban patterns.

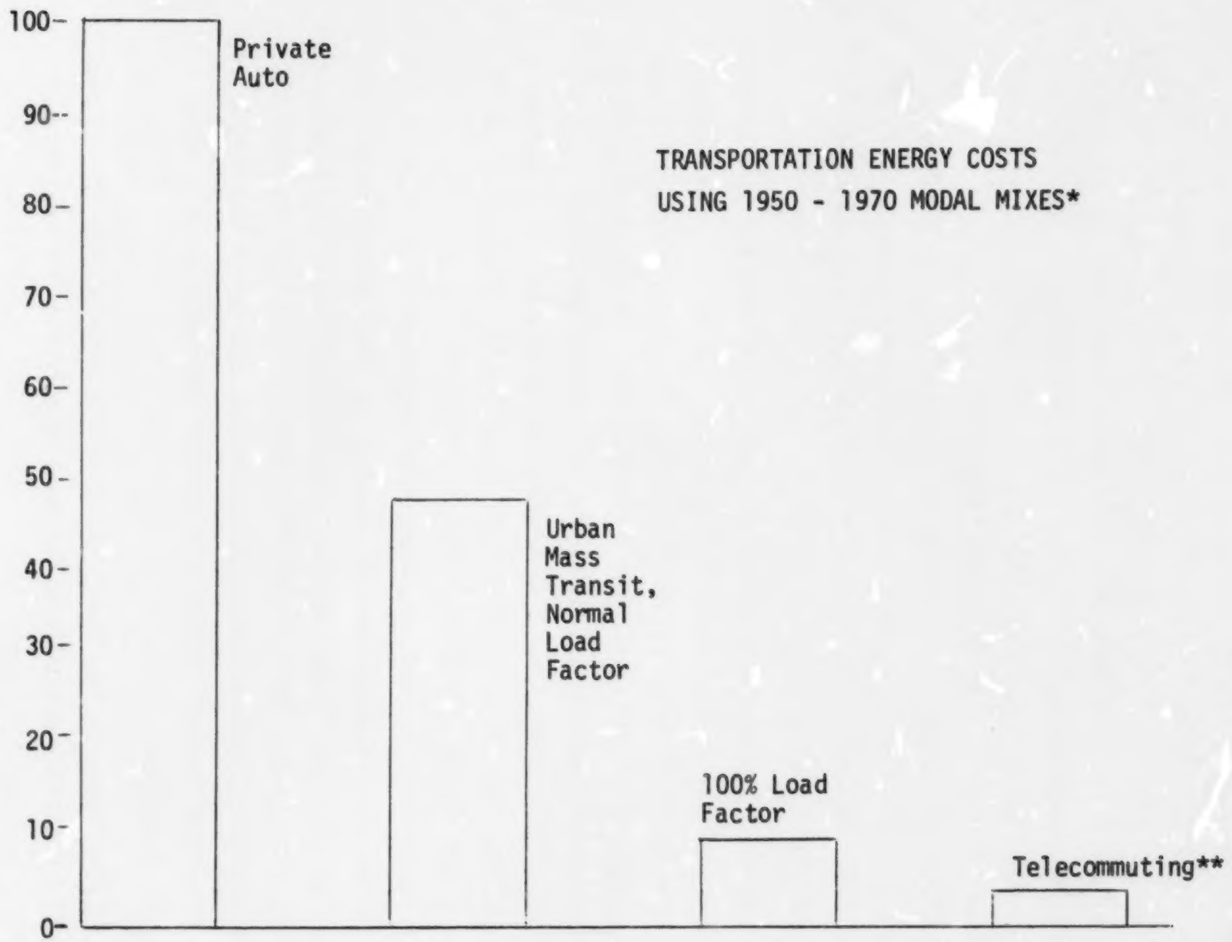
SOURCE: Reference 111, p. 484.

further dispersal outside the metro area may, as we have said above, not increase congestion, but will probably result in longer work trips requiring more gas and generating more pollutant emissions. To quote Harkness, "in terms of reducing commuting, a location about halfway between the center city and the urban periphery is best ... available data suggest that average trip length is highest [when jobs are located] in the CBD, declines to a low near the boundary of the inner city and post-WW II suburbs, and rises again in the outer suburbs." (111, p. 508)

Nilles, who is involved in directing a National Science Foundation-sponsored research project at the University of Southern California on telecommunications alternatives to urban transportation, arrives at similar conclusions regarding the shortening of the work trip when job locations are dispersed, and goes on to explore the communications facilities required and the comparative costs of decentralization to the firm studied. In this example, average company commuting distance is reduced from 11 to 3 miles with the dispersal of departmental functions to 18 smaller work centers; increasing the number of centers to 35 does not shorten the distance significantly. In a description of the project given by Nilles at a CalTech seminar this year (208), he stressed that this result does not extend to what he calls organizational fragmentation, where a corporate office is located downtown and large organization subunits are located in regional satellites. In this case, employees are likely to commute longer distances to work than if operations were centralized (208, p. 9). Shorter work trips and the resulting benefits occur only if the firm "disperses"—employees work at locations near their homes with up to 100 employees of the same organization, not necessarily all from the same department—or "diffuses"—nearby employees may work in the same location for different employers. The dispersed organizational form requires telecommunications using private data networks or leased telephone lines to perform intra-organizational communications, whereas diffusion requires a widespread capability for switched data networks, in other words, a more sohpisticated system of higher capacity than is now available.

The case of the insurance firm which is examined in the NSF project corresponds to the dispersed organization. The energy and cost savings given in Dr. Nilles' lecture are recorded in Table 4-1. The rough comparison made shows that marginal private commuting cost and the cost to the firm per employee of providing telecommunications facilities appear to be about equal, with the firm gaining an additional advantage from dispersion in lower rents and lower recruitment and training costs. A "simplistic calculation" of savings in operating energy costs, reproduced as Figure 4-3, shows that it would cost many times less to "commute with telecommunications" than by car. In this figure, the cost of gasoline for auto and transit commuting is compared with the cost of fuel energy at central power plants for telecommunications. Nilles also gives what he calls an "offhand estimate" that if 10 percent of the commuter population were converted to the dispersed organizational form described above, roughly 150 billion kilowatt hours a year would be saved on a national basis.

Even more interesting is the fact that in their examination of the substitutability of clerical and middle management employee functions, Nilles'



*From Hirst, E. "Energy Intensiveness of Passenger and Freight Transportation Modes."
**Includes electrical power plant energy losses.

Figure 4-3. Relative energy consumption per commuter for intraurban commuting.

SOURCE: Reference 208, p. 35.

group found that all functions, with the possible exception of training, are amenable to the use of telecommunications equipment operating at phone-line bandwidths (208, p. 27). Higher bandwidth operations for video management conferencing may be occasionally necessary, it was found, "but they are very infrequent and, if developed as a separate service, are not a major impact on the costs of the system although they may have a major impact on the management decision to use the system." (208, pp. 27-28)

This means that telecommunications could begin substituting for travel through the dispersion of organizations as proposed by Nilles using existing telephone network capacity, while widespread use of high-capacity video facilities would require substantial increases in present network carrying capacity. As Nilles puts it, "there is not an awful lot of research and development required to do a reasonable amount of dispersion right now." (208, p. 34) The biggest problem, as he sees it, "is finding out whether the telephone companies could handle the increased load required by the system ... we are in very close coordination with one of the local telephone companies in trying to determine the detailed costs and the impact of this new operating possibility on their network." (208, p. 34)

The National Science Foundation project in which Nilles is involved also intends to examine the question of environmental impacts of substitution of communications for travel. Certainly the savings in gasoline consumed by autos imply a reduction in vehicle emissions, provided that employees' nonwork auto trips do not increase by as much as the decrease in work trips.

OVERALL EVALUATION. Of the possible approaches to substituting communications for travel, developing neighborhood and suburban work centers through the extended use of present communications facilities seems to be the most doable at the present time. It would be rewarding for a demonstration of this approach, patterned after Nilles' dispersed organization concept or Harkness' commuter shed split concept, to be carried out in order to test the validity of projected benefits derived by these two authors using computer models. In the short run, however, no significant national impact in terms of reduced congestion, air pollution, or energy requirements can be expected from pursuing this approach unless such an innovative structuring of work and use of communications for intraoffice interaction becomes commonplace. It remains to be seen, for example, to how many businesses it would apply. A report prepared for UMTA by a Stanford University professor (152) estimates on the basis of a careful sorting out of Bay Area commuter trips by Bureau of Labor occupational classifications that 22 percent of peak-period auto work trips are *susceptible* to substitution by communications in the sense that their "ideational" or transactional nature would permit their performance from a remote location. However, like others who have attempted this kind of analysis before without such good data on the combined employment and trip characteristics of commuters, the Stanford author's decisions about susceptibility are based on common sense and not practice.

An even more serious question relates to changes in individual travel patterns if employees are given the option of working closer to home. Both the Harkness and Nilles modeling exercises are based on the use of gravity models, which assign trips to a transportation network according to a trip minimization rule. If people do not in fact minimize home-to-work distance in their choices of residences and jobs, the validity of such exercises must be seriously questioned. This objection would not apply if employees were required to work at the work center nearest them. It is more likely, however, that work trip distances will decrease initially with dispersion of office functions to locations chosen to be near employees' residences, but may increase as time passes and old employees move to better neighborhoods and new employees are engaged who live outside the area. As long as freedom of residential location and job choice prevails, people will choose their homes for one set of reasons and their jobs for another. Empirical analysis has disproved the academic tradition which cites the journey-to-work trip length as a factor in residential location (See INTERPLAN's report, 140, p. 67; R. J. Johnston, Urban Residential Patterns, An Introductory Review [New York: Praeger Publishers, 1971]; and John B. Lansing and Nancy Barth, Residential Locations and Urban Mobility: A Multi-Variate Analysis [University of Michigan, Survey Research Center Institute for Social Research, 1964]).

Last but not least, several researchers have raised the issue of the impact on transit use of substituting telecommunications for travel (72, 111, 208). If economic activity becomes more dispersed, then the population density may decrease to a point where it is insufficient to support fixed-schedule, fixed-route bus and rail services. As Harkness puts it, "If this [CBD] growth does not occur as expected, rail systems intended to serve it will almost certainly become billion dollar white elephants." (111, p. 509) About the only way to combine the benefits of decentralization (i.e., shorter trips) with high transit usage, he goes on to say, would be to place jobs in a ring of satellite centers linked by a high-speed circumferential transit line. "Then, *if* the service on this circumferential line were truly competitive with circumferential freeways in terms of speed, *if* the new office structures were built directly over stations, and *if* parking lots were provided at stations *between employment centers* rather than adjacent the center [sic], a reasonably high transit use seems probable." [Italics in original.] (111, p. 510) There would seem to be a tradeoff, therefore, between the strategy of substituting communications for travel and that of providing improved auto alternatives, at least in terms of conventional transit. It should be remembered, however, that the type of dispersed, relatively low-density travel which is likely to increase with decentralization is ideally suited to para-transit services (see 1.3 in Section 1 above).

Install Home Communications Centers (4.1.3) and Increase CBD Residential Facilities (4.2.3)

As mentioned in the introduction to this section, these actions are of minor importance in comparison to the communications-land-use pairs discussed above. Despite the proliferation of scenarios by technology addicts depicting the home communications center of the future (see INTERPLAN's report, 140, pp. 67-70), even the most carefully packaged system, i.e., Dickson's super telephone (see 72, Chapter 5, "The Videotelephone of the Future"), is not going to be available to the telephone subscriber for at least 25 years because of the tremendous increase in transmission capacity and capital required to provide such a system. Dickson believes that it will be adopted sooner in the information-based business and institutional communities because of its ability to transfer information at a high rate (72, p. 62). But even if such a system were to become available to the public, through the telephone system or as part of a home cable TV system, relatively few homes would have sufficient space to accommodate one, or more likely two, work-at-home adults in the kind of privacy required for all but the most mechanical of tasks. More research is needed to determine the mental health effects of working at home; it has often been suggested that most people would not choose to work at home even if they could, because of a psychological need to interact with a social-occupational environment and peer group.

Increasing CBD residential facilities as a travel reducing action is subject to the same weakness as providing suburban employment, with the exception that certainly the historical trend towards suburban living favors the latter more than the former. Given the choice between living close to work downtown and living on a relatively less expensive, larger lot out of the city, employees with children are likely to choose the latter even if the available supply of in-town housing is increased. On the other hand, this type of housing should not be neglected so that the option of downtown living remains open to downtown workers whose life styles are more compatible with a smaller, apartment-type of existence, e.g., unmarried young singles and older couples whose children have left home.

SECTION 5

REDUCED VEHICULAR EMISSIONS (5.0)

INTRODUCTION

The four phenomena reviewed in the four previous sections do in fact have some impact on all of the goals—mobility, air quality, and energy conservation—by improving vehicular flow (2.0), reducing auto VMT (3.0), reducing demand for travel (4.0), or increasing the use of non-auto modes (1.0). In contrast, the strategies promoting phenomena 5.0, reduced vehicular emissions, are most likely to have little or no direct impact on any goal except reducing air pollution, although their indirect effects are expected to raise the cost of auto maintenance, fuel, and of the vehicles themselves, contributing to strategy 3.2, increased cost of auto use. Also, to the extent that these strategies will fail to close the gap between present emission levels and the EPA emission standards by the legislative deadline, strong pressure will be generated to force, by legislation or regulation, implementation of other strategies contributing to the increased use of non-auto modes (1.0) and to reduced urban auto use (3.0). This pressure to attain the air quality standards, coming from an agency with strong regulatory and legal powers, could catalyze actions to pursue these strategies which would reduce congestion and energy use as well as air pollution. However, the reduction of emissions through emission control devices may bear a fuel penalty. Indirectly, therefore, a "hard-line" pursuit of reduced vehicular emissions could have a dampening effect on congestion and air pollution; its impact on energy use would depend on the balance between the increased fuel requirements of cleaner cars and reduced fuel consumption due to auto use restraints and shift to transit modes; its impact on mobility would be negative to the extent that travel options were curtailed.

Therefore, in line with the limitation of the study scope to examining only those aspects of air pollution and energy usage which are interrelated with UMTA's goal of providing for urban mobility, we investigate in this section the extent to which emission control strategies will (1) reduce emissions (2) raise the cost of auto ownership and use, (3) necessitate transportation controls in cities, and (4) change fuel efficiency. However, no attempt is made to quantify the tradeoff between the possible energy savings due to the increased cost of auto use and travel restrictions imposed in order to enforce air quality, and the energy penalties due to changes in engine technology required for emission control; our interest in these reciprocating effects is confined to their impact on the cost of private vehicular travel.

Table 5-1 summarizes the impacts of the three strategies to reduce vehicular emissions. New vehicle certification and inspection and maintenance are the most effective short-term strategies for reducing vehicular emissions, but in many urban areas, including the four singled out for attention in this report, these strategies alone will not obviate the need for other controls. Of these "other" transportation control strategies, bus and carpool lanes (2.1.3) is deemed a first priority item by EPA, and vehicle retrofit (5.1.2), bicycle lanes (1.4.2), carpool matching programs (3.1.1), mass transit expansion and improvement (1.1, 1.2), reduction of on-street parking (3.3.2), and traffic flow improvements (2.1.2) are second priority items (336, Appendix D). Implementation of these strategies in order to meet air quality deadlines could also have a substantial impact on urban congestion, mobility, and energy use, as is indicated by the results of the Volume 2 exercise to determine the impact of a 1990 modal mix heavily shifted to transit. This analysis showed that a great enough shift to transit could reduce HC and CO emissions up to 30 percent by 1990, possibly mitigating the need for the severely reduced emission levels of 1976-1977.

The 1967-1973 losses in fuel economy due to engine modifications to clean emissions may be recouped in 1975 and later model cars if auto manufacturers are allowed sufficient time to convert production to cleaner engine types. Otherwise, serious fuel penalties can be expected since conventional spark ignition engines cannot be made to run cleaner than the '75 interim standards without reducing fuel economy. Increased fuel requirements would increase auto operating costs; conversion to cleaner and more fuel-efficient engines will increase vehicle cost. However, these cost increases are likely to be minor compared to further expected price increases due to inflation and petroleum shortages and market disruptions.

Table 5-1. Documented impact of strategies and actions on offsetting phenomena: Legislate Maximum Mobile Emission Levels (5.1), Legislate Fuel Specification Changes (5.2), and Introduce Non-Polluting Petroleum-Based Engine Designs (5.3).

PHENOMENA			COST ESTIMATES
1.0 Improved Auto Alternatives; 2.0 Improved Vehicular Flow; 3.0 Reduced Urban Auto Use; and 4.0 Reduced Urban Travel Demand	5.0 Reduced Vehicular Air Pollutant Emissions	6.0 Reduced Vehicular Petroleum Consumption	Increased Auto and Fuel Costs
LEGISLATE MAXIMUM MOBILE EMISSION LEVELS (5.1)			
	Certify New Vehicles (5.1.1)		
References 85, 142 and 243 The 29 AQCRs where stationary source controls and implementation of motor vehicle emission controls will not be sufficient to attain the required ambient air quality standards have been required to submit for EPA approval transportation control plans which include many of the strategies and actions listed under INTERPLAN's phenomena 1.0, 2.0, 3.0 and 4.0.	New 1975 models meet emission standards set by EPA (1.5 g/mi. HC; 15 g/mi. CO; 3.1 g/mi. NO_x; and 2.0 g/test for fuel evaporatives), which represent about a 67% reduction over 1970-71 emission levels (56% for NO_x); a 90% reduction is ultimately required. However, reduced vehicle emissions due to attrition of older, less controlled cars will not in themselves be sufficient for attainment of ambient air quality standards in urban areas.	Fuel economy losses of 13 to 20% over 1967 levels have been attributed to emission controls required in 1973/74 model cars. EPA tests of 1975 models indicate increases of 13.5% (average) in fuel economy over 1974 cars. FMC claims 1976/77 standards and safety requirements will reduce fuel efficiency by 25%.	Emission control devices and techniques in 1975 model cars will cost consumers $24.45 more per vehicle, plus $125 more for cars sold in California, which must meet stricter federal standards. Estimates made in 1972 ranged from $350-500 per vehicle for changes to meet 1976 standards; these standards will not have to be met until 1977 or 1978 because of 1974 energy conservation legislation. Henry Ford II says further emission reductions and safety devices will cost $750/car and will require a $1 billion investment by Ford.
	Require In-Use Vehicle Retrofit (5.1.2)		
References 3, 98, 133, 236, 336 and 337 Retrofit is not in itself sufficiently effective over and above the impact of reduced emissions from new cars to obviate the need for inspection and maintenance (5.1.3) or further transportation actions.	EPA considers retrofit a second-priority measure. Could reduce overall CO emissions 5% by 1975, or possibly 7-8% by 1977.	Possible increase in fuel requirements if device is improperly installed or maintained.	Average cost of retrofit device for pre-'75 cars could be $200. 1974 California NO_x devices required to sell for less than $35.
	Require Inspection and Maintenance (5.1.3)		
References 142 and 336 In seven AQCRs, inspection and maintenance and vehicle retrofit measures should obviate the need for further transportation controls. 19 other regions will require such measures.	Cornerstone of most control strategies; considered a first-priority measure by EPA. Permits 8-12% reduction in HC and CO.	No effect.	No effect.

Table 5-1. (continued)

PHENOMENA			COST ESTIMATES
1.0 Improved Auto Alternatives; 2.0 Improved Vehicular Flow; 3.0 Reduced Urban Auto Use; and 4.0 Reduced Urban Travel Demand	5.0 Reduced Vehicular Air Pollutant Emissions	6.0 Reduced Vehicular Petroleum Consumption	Increased Auto and Fuel Costs
LEGISLATE FUEL SPECIFICATION CHANGES (5.2)			
References 142 and 156 Does not affect the need for transportation controls.	Indirect impact only. Unleaded fuel required for cars equipped with catalytic converters.	Some loss in fuel economy due to lower octane rating of unleaded fuel. Raising octane rating back into the 94-100 range by added lead would save 2% in crude petroleum.	Unleaded gas costs as much as premium (3¢ more than regular), but should save $25-45 per vehicle per year in maintenance costs due to longer muffler and spark plug life.
INTRODUCE NON-POLLUTING PETROLEUM-BASED ENGINE DESIGNS (5.3)			
References 85, 142 and 301 Cleaner engines could eventually make transportation controls unnecessary in most cities, but not until such engines are in most cars; this is not likely to happen until late 1980s or early 1990s.	Could be the best long-range strategy if the deadline for attaining emission controls and ambient air quality standards were to be sufficiently delayed. See Table 5-2 for emission characteristics of individual engine types.	Stratified charge, diesel, Stirling, and gas turbine engines would give better gas mileage than conventional engines. See Table 5-2 for fuel use characteristics of engine types.	Not known; likely to be relatively higher if EPA presses the auto industry for unreasonably speedy production switchover. Fuel costs will be lower due to better fuel efficiency.

LEGISLATE MAXIMUM MOBILE EMISSION LEVELS (5.1)

Certify New Vehicles (5.1.1)

The federal motor vehicle emission standards for light-duty vehicles in grams per mile of CO, HC, NO_x, and fuel evaporatives, are given in Table 15 in Volume 4 (142, p. 41). Implementation of the 1976 and 1977 standards shown in the table has been extended for at least a year and possibly until the 1978 model year by the Energy Supply and Environmental Coordination Act of 1974 (Los Angeles Times, 13 and 23 June 1974), in order to conserve energy. The 1975 standards must still be met, including the more stringent levels required in California, but stiffer requirements would not go into effect until the 1977 or 1978 model years.

U.S. and foreign car manufacturers have complied with the 1975 standards; with about 95 percent of all new domestic and imported models tested, the EPA reported that all new cars meet the standards (Los Angeles Times, 21 September 1974). Most car manufacturers have installed catalytic converters in their 1975 models, although not all cars will require them in order to meet the standards. American Motors Corporation, for instance, while equipping all California cars with converters, will equip only 8-cylinder engines (25 percent of their total production) with the converters in other states (Los Angeles Times, 12 September 1974).

Estimates made in 1972 of the cost of these modifications to the consumer ranged from $350 to $500 per vehicle by 1976 (2, p. ix), but announcements made in September 1974 by the major car manufacturers indicated that the cost for new federally mandated antipollution equipment will be about $104 per vehicle in 1975 (Ford; figures for other manufacturers not given), plus $24 (GMC), $45 (Ford), or $125 (AMC) more in California, which has stricter requirements (Los Angeles Times, 16 September 1974). These cost increases account for about 30 percent of the total expected 7.5 to 8.6 percent increase in 1975 car prices over 1974 prices; the rest is due to rising costs, increased shipping charges, and optional equipment which has been made standard (Los Angeles Times, 13 September 1974). FMC's chairman, Henry Ford II, has predicted that government regulations requiring further safety and emission control devices by 1978 could add $750 to the cost of a car, in addition to increasing fuel requirements (Los Angeles Times, 1 October 1974).

On-schedule implementation of EPA's 1977 vehicle emissions standards, which are equivalent to a 90 percent reduction over 1970-71 emission levels (1975 standards represent a 67 percent reduction for HC and CO and 56 percent for NO_x emissions) and its stationary source control standards would make it possible for about 40 percent, or 17, of the nation's 43 major metropolitan air quality control regions (there are 250 AQCRs in all) to attain the ambient air quality standards (see Table 14, p. 41, and p. 188, Volume 4). Seven regions, including Seattle, will be able to achieve the standards by 1975 through inspection and maintenance programs (4.1.3), and substantial improvements in transit (1.1, 1.2); 19 more will also require vehicle retrofit (5.1.2) and other transportation controls to reduce vehicle miles traveled. Of these 19, Philadelphia and 4 other regions will be able to meet the standards by 1977, but the remaining 14, including Los Angeles and Baltimore, cannot be reasonably expected to meet the air quality standards even by 1977 (see Volume 4, p. 189).

While the fuel economy penalty for achieving the 1976 or 1977 emission standards will not be known for sure until car models designed to meet these standards become available for testing, there is some hope that it will be less than has been predicted. For one thing, fuel economy gains in the 1975 models reported by EPA almost recapture fuel economy losses (over 1967) due to earlier emission control devices. This is due to the availability for the 1975 models of catalytic converters, which help to complete conversion of exhaust gases, permitting better tuning of the engine. While it is also true that cars to be sold in California, which must meet emission standards falling somewhere between the 1975 and 1976 prescribed federal levels (for CO and HC; the NO_x level required is the same), may show less of a gain in fuel economy (Ford President Lee A. Iacocca estimated 10 percent fewer mpg for 1975 California cars; 85), the 1974 energy-saving delay in the implementation of the 1976 and 1977 standards may allow auto makers time to convert production to cleaner, new engine types (see 5.3 below) which also have better fuel economy. There is no consensus on this issue, however; Ford's chairman claims safety and emission control devices required by 1978 would increase fuel requirements by 25 percent (85).

Require In-Use Vehicle Retrofit (5.1.2)

Retrofit of precontrol (1966 and older) vehicles and of 1968-75 cars to meet the 1975 standards is regarded by EPA as a second-level action to supplement the gradual replacement of old vehicles by new ones. The evaluation of the effectiveness of this action in reducing vehicle emissions is currently in a state of flux. A recent EPA memo cautions (337, p. 3):

> "Significant technical and economic questions have been raised concerning catalytic retrofits on light-duty passenger vehicles, and in view of these uncertainties I do not believe it would be prudent to undertake a major enforcement action in this area without consulting with [the] enforcement staff, which will keep track of the technical data through [the] office of transportation and land use policy.
>
> "In other retrofit situations, a cautious enforcement approach may be warranted if there is a particularly compelling case of adverse economic impact on low-income groups and a showing by the affected community that the benefits of the retrofit program would be only for a very short term period, i.e., that the ambient standard clearly would be attained *in just a few years* without such a program." [Italics added.]

Light duty vehicle retrofits are indicated as a "Priority II" measure in an EPA enforcement memo, while inspection and maintenance (5.1.3) and exclusive bus and carpool lanes (2.1.3) are considered "Priority I" measures (336, Appendix D). This view is supported by a 1972 EPA report which found that a typical retrofit program applied to pre-1968 autos would probably reduce overall CO emissions by less than 5 percent in 1975, until more sophisticated emission control technologies than then available, e.g., catalytic converters (to be built into most 1975 cars), thermal reactors, or exhaust gas recirculation could be applied (133).

A cost-effectiveness analysis of various EPA-recommended transportation control strategies as applied to Baltimore and Boston evaluates retrofit of pre-'75 vehicles as potentially capable of reducing 1977 emissions in Baltimore by 7 percent, or 3-4 percent less than offered by inspection and maintenance (a more expensive strategy) or traffic flow improvements (a less expensive one) (3, p. 26). However, while retrofit would be relatively effective to 1977, its effectiveness decreases in the following years as 1975 and later model cars become more dominant in the vehicle population (p. 21). A similar picture emerged from Boston, where retrofit, inspection and maintenance, and a trip surcharge emerged as the strategies with the highest impacts on 1977 emissions (8, 10, and 9 percent reductions in 1977, respectively) (p. 40). Even so, a vehicle retrofit program cannot in itself obviate the need for other transportation control strategies.

The above-mentioned report assumes that retrofit of pre-'75 cars will cost $200 per vehicle, but the cost may not be so high. Under a 1973 California law requiring that NO_x control devices cost no more than $35, five such devices have been certified by the state Air Resources Board (98) and are due to be installed on all 1966-70 models in the South Coast Air Basin by June 30, 1975 (98, 236).

The impact of retrofit on fuel costs depends entirely on the type and effectiveness of the device and whether it is adequately maintained.

Require Inspection and Maintenance (5.1.3)

Periodic mandatory inspection of vehicles' emission control equipment is generally regarded as the most powerful means of reducing emissions, next to requiring lower emissions of new vehicles. The EPA enforcement memo (336, p. 4) calls it "the cornerstone of most control strategies," which can not only permit large emission reductions (8-12 percent HC and CO), but helps assure that emission reductions claimed for new vehicles (5.1.1) are in fact achieved.

Despite the current lack of regular state vehicle inspection programs which might incorporate inspection and maintenance (I&M) procedures (New Jersey, Chicago, and Arizona are the only three places with I&M programs currently underway), I&M programs will probably go into effect soon in many states, since 29 AQCRs have proposed such programs as a component of their air quality implementation plans, and since this program is high on EPA's priority list for enforcement.

The implementation of such a program should not per se increase the cost of auto use nor have any effect on fuel consumption, but it has in seven regions obviated the need for further transportation control strategies other than transit improvements; such further measures are however required for 19 regions also planning retrofit, maintenance and inspection measures (see Volume 4, p. 189).

LEGISLATE FUEL SPECIFICATION CHANGES (5.2)

The removal of lead additives from gasoline, which lowers fuel octane ratings and fuel economy, is probably only a temporary strategy in the reduction of emissions. Its current necessity is due to the fact that the most popular add-on device developed so far to combat noxious exhaust gas emissions in conventional engines, the catalytic converter, is damaged and eventually rendered inoperative by the lead compounds used to raise octane. When or if other exhaust processing techniques, such as the thermal reactor now used on Mazda vehicles, are put into general use or new engines are developed, non-leaded gas may no longer be required. This measure is therefore less a strategy for reducing emissions than a temporary condition required for the operation of catalytic converters, which do reduce emissions.

While unleaded gas will cost more (3¢ more than regular, or about the same as for premium gas), maintenance savings to car owners using unleaded gas have been estimated at $25-45 per vehicle per year, due to increased muffler and spark plug life (Environmental News, 3 May 1974).

The question of octane rating is of minor importance to the emissions issue. Lowering octane rating may increase NO_x emissions due to increased "engine knock" and decreases fuel economy; it is, so far, a necessary consequence of removing lead additives. The savings of crude petroleum from raising the octane rating back to the 94-100 range will not exceed 2 percent (156, p. 919).

INTRODUCE NON-POLLUTING PETROLEUM-BASED ENGINE DESIGNS (5.3)

There is little to be gained in emission reductions and much to be lost in fuel economy, overall cost, maintainability, and durability by pursuing improvements to the conventional spark ignition engine. One alternative spark ignition engine, the stratified charge, offers major advances in emission reductions and fuel economy, while the other current alternative design, the rotary engine, now marketed by Mazda of Japan, shows poor fuel economy and insignificant inherent emission reduction gains compared to the conventional engine. For these reasons, GM has indefinitely shelved plans to produce the rotary engine it has developed (Los Angeles Times, 25 September 1974).

Non-conventional petroleum-fueled engines, such as the Stirling, diesel, and gas turbine, could meet the 1975 and 1976 emission standards but are not likely to be in mass production before 1980, except for a non-improved diesel engine which could meet the '75 but not the '76 standards (see Table 5-2).

Table 5-2. Characteristics of advanced non-spark ignition engine technologies.

	Diesel	Advanced diesel	Gas turbine	Advanced gas turbine	Battery	Advanced battery	Rankine	Advanced rankine	Stirling	Advanced stirling	Advanced "other"	Advanced fuel cell	Precontrol gasoline
Emissions	1975	1976?	1975	1976?	C.p.p	C.p.p	1976	1976	1976	1976	1976	1976	
Fuel versatility	F	G	E	E	C.p.p	C.p.p	E	E	E	E	E	E	G to E.
Fuel consumption	¾	¾	1 to 2	¾ to 1½	¾ to 1	¾ to 1	1½ to 2	1½	¾	½ to ¾	~¾	½ to ¾	1.
Noise	F to G	G	E	E	E	E	E	E	E	E	E	E	G.
Safety	E	E	E	E	F	G	G	G	E	E	E	G	E.
Cost	2	1	2 to 3	1	>5	2½ to 3	3	2½ to 3	1½ to 2	1	1½ to 2	10	1.
Starting ease	Ewde	Ewde	Ewde	Ewde	E		Ewde	Ewde	Ewde	Ewde	Ewde	Ewde	G.
Response to abuse and neglect.	E	E	G	E	F	(?)	F to G	F to G	P	E	E	(?)	E.
Driveability	G	G	G to E	E	P to F	E	G	G	G	E	G to E	E	E.
Serviceability	E	E	E	E	G	G	P to E	E	P to E	E	E	G	E.
Design Hp versatility	F	E	F	F	F	E	F to G	G	E	E	E	E?	E.
Control ease	E	E	F	F	E($)	E(?)	P	P	G	E	F to E	G?	E.
Producibility	G	G	F	G	G	G	P	G	G	E	G to E	E	E.
Size	2¼	¾	1	1		1½	1½	1	¾ to 1	¾	1	3+	1.
Weight	2 to 2½	¾	¾ to 1	½ to ¾		1½	1¾ to 3	1¼ to 1½	1 to 1¼	⅔	1 to 1½		
Integrability	F	E	E	E	P	E	P	P	G	G	G	E	E.
Present production status	Limited production.	−4 yr	Commercial feasibility.	−4 yr	Limited production.	−4 yr	−2 yr	−4/−6 yr	−2/−3 yr	−5/−10 yr.	−5/−10 yr.	−15 yr	Mass production.
Earliest limited production	Now	1980	1978	1982	Now	1980	1979	1981	1979	1981	1981	1992	Now.
Earliest mass production	1976	1983	1984	1984	1976	1984	1983	1985	1983	1984	1984	1996	Now.

P—Poor.
F—Fair.
G—Good.
E—Excellent.

C.p.p.—Central powerplants.
Ewde—Excellent, with delay.
Yr—Years to prototype.
E($)—Excellent, but costly.

Note:

Numerical designations for fuel consumption, cost, size and weight of engine types are given as a proportion of the pre-controlled gasoline engine characteristics (see last column).

SOURCE: Reference 301, p. 127.

Therefore if the attainment of the light-duty motor vehicle standards were to be postponed until 1980 or later, this strategy would be the strongest and

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most effective in the long range for improving both air quality and fuel economy. Ford Motor Company said in 1973 that it could have the stratified charge engine it has been developing in about 500,000 of the 1977 models if the EPA could clarify whether this engine would be acceptable despite its shortfall in NO_x emissions. Further delays in this clarification have pushed back the estimated feasible production date to 1978 (85). The availability of new engine types would not, however, reduce the need for additional transportation control strategies in regions until such time as these engines greatly outnumbered older, conventional engine types.

SECTION 6

REDUCED VEHICULAR PETROLEUM CONSUMPTION (6.0)

INTRODUCTION

The three strategies promoting phenomena 6.0 have little direct impact on any goal except reducing vehicular petroleum consumption, but their indirect effects can create strong incentives to implement auto alternatives (1.0), reduce urban auto use (3.0), and reduce urban travel demand (4.0), and to not implement emission reductions (5.0). Restricting vehicular use by limiting fuel supplies (6.2.2) could force some travelers to seek alternatives to the auto or to travel less; the price increase in gasoline accompanying a lower supply of fuel will increase the cost of auto use (see 3.2.3, Section 3), and thereby reduce urban auto use. Demanding maximum fuel economy from present autos (6.1) implies, in the extreme, abandonment of vehicle emission standards. It is more likely, however, that in the interest of energy conservation, the 1976 standards will continue to be postponed; they have already been delayed to 1978. The fuel economy-emission reduction tradeoff has, in any case, become less important since the announcement this fall that use of the catalytic converter in 1975 models has permitted these new cars to achieve 1967 fuel economy performance, sacrificed in the 1968-1974 period due to the emission control techniques required before the catalytic converter became available.

IMPROVE FUEL ECONOMY (6.1)

Reduce Vehicular Size and Weight (6.1.1)

EXPERIENCE. The introduction of more "compact" domestic models and the importation of small foreign cars enables the motoring public to have a greater choice of fuel-saving automobiles. With increasing fuel prices and possible fuel shortages, greater use of small cars benefits both the public and the national economy. Individuals may retain their current individual mobility while lowering fuel consumption and maintaining or decreasing other vehicle operating costs (301).

The small car market share increased from 1970 (30%) to 1973 (39%), of which nearly half (16% of the total 1973 market) were imports (301, p. 418). The chairman of American Motors has predicted that small cars will capture 50 to 55 percent of the 1975 market (Business Week, 14 September 1974).

Continued planned increases in the domestic production of small cars (and especially of small engines) will require considerable modification of existing plants or construction of new factories, which should take 2 to 4 years and cost some $4 billion (168, p. 1). While auto manufacturers are proceeding with this retooling, in general, they prefer to sell large cars, as symbolized by an oft-quoted maxim of Henry Ford II: "Mini cars mean mini profits." More diplomatically, GM says it believes in offering a car for "every taste and every budget." (Los Angeles Times, 20 September 1974) While most 1977 GM cars will shrink by about half a size (ibid.), no U.S. auto manufacturer's plans include a car that would match the roominess and gas economy of the Mercedes or the Volvo, or the optimal design of the small Fiat 128 (Business Week, 14 September 1974). European manufacturers such as British Leyland and Volkswagen have recently announced that they are now designing a so-called 50-50 car with the dual objectives of 50 miles per gallon gasoline economy and a cruising speed of 50 miles per hour. Both manufacturers state that the 50-50 model will be in production in 1976. American principal automakers are not prepared to design anything approaching the European target. This example shows how much elbow room there still is be-

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tween what, according to Europeans, is technically possible within the existing state of the art, and what American automakers are prepared to supply.

IMPACTS ON GOALS. Very small "city cars", prototypes of which have been developed in England and Japan, have an obvious advantage in dense city traffic. They also require less parking space. A number of "city car" prototypes developed in England, mostly 2-seaters, weigh only 400 to 1200 lbs., have a wheel base of 50" to 70", speeds of up to 50 mph, and fuel consumption of up to 70 mpg (293). This compares to an average U.S. car weight of 4275 lbs. for 1973 models with a fuel economy of about 13 mpg (301, pp. 496, 499).

In city driving the reduction of car weight by 100 lbs. results in 0.25 mpg fuel saved (301, p. 496). Weight reduction, to be fully effective, should be accompanied by improved aerodynamic profiles, radial tires, improved transmissions, and increased compression ratios of engines (to improve their thermal efficiency). This last requirement is in direct opposition to reduction of pollutant emissions (301, pp. 447, 496, 499). Average improvement in fuel economy of 13 percent by 1976 and 25 percent by 1978, relative to 1973 models, is a realistic goal which is achievable through reduction in the size of vehicles (301, p. 410).

Smaller, lighter cars also normally require smaller (4 or 6 cylinder) engines, which consume less fuel and emit proportionately fewer pollutants (301, p. 468). However, intrinsically "cleaner" engines are more difficult to fit into smaller cars (21), but it can be done: Honda has produced a car with a stratified charge engine which meets 1975 EPA standards and has in-city fuel consumption of approximately 23 mpg (301, p. 134).

COST FACTORS. The basic unit for pricing autos is their weight, since steel is the most important component. The current Detroit "average" figure is $.80-1.15 per "basic" pound for cars made of steel (see Table 6-1). It follows that full-sized sedans weighing 4-5,000 lbs. are not sold below $.92/lb., compacts in the 2,400-2,900 lb. weight class sell for an average $.85/lb., and intermediates can be sold for as little as $.76/lb. Some small foreign cars which weigh only 2,600 lbs. sell in the U.S. (duty included) for approximately $1.30-1.50/lb. (see Table 6-1). The substitution of aluminum or plastics for steel is expensive and not effective from an energy savings viewpoint (301, p. 448). But smaller cars need less steel, glass, etc. and less energy at the "raw material" manufacturing stage (301, p. 468).

Table 6-1. Car prices per pound, 1974 models.

Make/type	Weight (lbs)	Base Price ($)	Price/lb. ($/lb.)
Foreign Imports (subcompacts)			
Dodge Colt	2,219	2,816	1.26
Fiat 128	1,963	2,684	1.37
Honda Civic	1,649	2,620	1.59
Subaru	2,003	3,040	1.51
Compacts			
Duster (Chrys.)	3,102	2,511	0.81
Maverick (Ford)	2,875	2,441	0.85
Hornet (AMC)	2,901	2,359	0.81
Nova (GM)	3,336	2,527	0.76
Mustang II (Ford)	2,810	2,895	1.03
Intermediates			
Chevelle (GM)	3,781	3,131	0.83
Matador (AMC)	3,632	2,996	0.82
Satellite (Chrys.)	3,613	3,118	0.78
Torino (Ford)	4,141	3,135	0.76
Full-Size Cars			
Mercury	4,955	4,888	0.99
Impala (GM)	4,620	4,268	0.92
Fury III (Chrys.)	4,430	4,051	0.92
Ambassador (AMC)	4,055	4,543	1.13
Dodge Monaco	4,412	4,096	0.92

SOURCE: Consumer Reports, January, March, April and June 1974.

Highway maintenance costs are also proportional to the weight of cars using the roadway, so a shift to lighter vehicles would result in lower highway maintenance costs (301, p. 468). User fuel costs are also lower for smaller cars, since the cost of fuel consumed by an auto during its life (10 years) approximates the first cost of the car (301, pp. 429-430).

Reduce or Eliminate Emission Control Fuel Penalties (6.1.2)

Estimated auto emissions of CO, HC and NO_x in urban areas for the period 1960-1990 under various assumptions regarding emission standards are shown in Figures 9, 10 and 11 of Volume 4 (see 142, pp. 53-54). Table 77 in Volume 4 (see 142, p. 155) shows that in the four cities studied in this report, maintaining the current exhaust emission program will ensure attainment of the ambient air quality standards by the mid-1980s except for the HC standard in Los Angeles. A postponement of the air quality standards would permit needed R&D to develop engine types which can be optimally applied to future transportation needs (301, p. 126). In other words, the greatest impetus to the development of new power plants that are both less polluting and that burn less fuel would be a more stable outlook for future emission standards, i.e., a more realistic timetable for implementation (301, p. 507).

The time constraints placed on the automakers by requiring substantial cleanup by 1975-76 gave them little time for serious R&D; they had to "tinker" with current engine technology. As a result, a major penalty in fuel consumption was paid due to spark retardation, lower engine compression ratios, and exhaust gas recirculation. Exhaust gas recirculation (EGR), the most frequent method used for reducing CO and HC emissions, results in a 1.05 percent loss in fuel economy for each 1 percent EGR (301, p. 492, Chart II). Each degree of spark retardation to lower CO and HC exhaust means a 1 percent loss in fuel economy (301, p. 494). Reductions in engine compression required by the emissions standards have increased fuel consumption by approximately 6 percent (301, p. 495), and Chrysler estimates that the 1976 fuel penalty will be 30 percent compared to 1967, 15 percent more crude oil due to the use of oxidation catalysts, and 15 percent more auto fuel due to NO_x requirements (0.4-1.5 g of NO_x). If the catalyst is not used, the engine has to be run very rich to get down to NO_x emissions, which wastes a lot of fuel. Thus, by 1975, more auto fuel will be consumed by autos without catalytic converters to meet the vehicle emission standards.

The costs of increased use of fuel to meet ambient air quality standards, estimated in EPA's 1972 Annual Report, are: for light-duty vehicles from 1968 to 1977, $64.7 million; for heavy-duty trucks, 1968 to 1977, $422 million (based on fuel prices of 33¢/gallon, 26¢/gallon for trucks). The national cost of compliance with EPA standards between 1968 and 1977 is estimated to be $26.9 billion. This includes both autos ($25.4 billion) and heavy-duty trucks ($1.5 billion).

More funds are needed for research on radically new engines such as the stratified charge engine. Mazda and Honda started their R&D much earlier than Detroit, and that is why they are now so much further ahead (301, p. 369).

Improve Engine Propulsion Efficiency (6.1.3)

EXPERIENCE AND IMPACTS. Average auto engine propulsion efficiency is approximately 15 percent; it has declined by at least 10 percent since WW II. (Maximum thermal efficiency approaches 30 percent.) Aside from accessories (air conditioning, etc.) and engine efficiency, the major factors which affect fuel consumption (mpg) are:

1. vehicle weight (80%)
2. automatic transmission (15%)
3. tires (5%)
4. power train matching (axle ratios and "overdrives")
5. aerodynamic characteristics of the vehicle body (air resistance). On the open road, aerodynamic drag accounts for up to 40 percent of the fuel used; in city driving, it is less than 5 percent.

The quickest and easiest way to lower fuel consumption of automobiles is to reduce their weight and size. Therefore, between 1976 and 1978 the main hope of reducing fuel consumption is to decrease the average size and power of vehicles, rather than to achieve better fuel economy for vehicles of a given size. It is basically very difficult to improve the thermodynamic efficiency of existing engines (301, p. 412).

In the long run, increasing the fuel use efficiency of an average car from 12 to 18 mpg would save 25 billion gallons of gasoline, or 1.2 billion bbl. of crude oil (301, p. 420). But even if a 25 percent improvement in fuel economy could be achieved overnight, it would take 10 years to achieve a 5 percent reduction in total petroleum consumption (301, p. 445).

The greatest stumbling block to a more efficient engine is the 1977 NO_x standard of 0.4 g/mile. The necessity of this stringent a requirement has been widely questioned. If the NO_x standard were relaxed, present uncertainty concerning the acceptability of new engine types which can meet the 1976 but not the 1977 standards would be resolved. More federal level R&D effort is required (e.g., a 5-year program at $20 million per year) to bring more efficient and cleaner alternative engine types to the production stage (301, p. 414). A review of these alternatives is given in the following pages and in Table 5-2 (p. 5-11).

ALTERNATIVE ENGINE TYPES.* The Transportation Energy Panel (TEP), under the sponsorship of the Department of Transportation and with participation from DOD, EPA, NASA and the Office of Science and Technology, prepared a report on R&D opportunities for improved transportation energy usage in 1972 (288). The chapter on technology opportunities at lower powers presents a well-documented and well-reasoned sequence of suggested R&D programs in automobile engine technology. The report's findings are summarized in Table 6-2, reproduced from the report, and briefly discussed below.

Stratified Charge Engine. Until now, Ford has concentrated its R&D efforts on this engine type, and could begin limited production (500,000 units) within perhaps two or three years of a clarification by EPA of future emission standards. TEP estimates the impact of the stratified charge engine on fuel consumption as primary, at least 20 percent better (in terms of mpg) than current engines (Ford says 25 percent), while it should closely approach EPA's 1976 emission standards. This engine will cost $300-500 more than a conventional gasoline engine. Since it will consume less fuel, the cost break-even point to the consumer would occur in 3-5 years.

Light Weight Diesel. At present, the weight of the diesel engine is approximately 5 lbs./hp as compared to 3-4 lbs./hp for gasoline engines. The DOD is now the prime sponsor of R&D aimed at bringing diesel weight to approximately 1-3 lbs./hp. There are no commercial efforts in this area in the U.S. TEP forecasts that EPA air quality standards could be met with diesels with a little extra effort; NO_x is the only problem at present. Diesel offers a 20-25 percent fuel savings as compared to gasoline engines of equivalent weight. The diesel engine also has an inherently broader tolerance for kerosene fuels, and hence it can relieve the demand for low or no-lead gasoline. A diesel engine would cost $300-500 more than a gasoline engine of the same rating. Since fuel consumption is lower and the fuel used cheaper than gasoline, the consumer break-even point should occur in 1-5 years. The life expectancy of a diesel engine is 2 to 3 times that of comparable gasoline engines. Possibly for this reason, in London, Paris, and most German cities most taxis run exclusively on diesel engines.

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*Electric vehicles are discussed under 6.3.2 below (pp. 6-20 - 6-28).

Table 6-2. Comparisons of advanced engine types with anticipated 1976 and pre-1969 Otto internal combustion engine.

	Efficiency	Emissions	Weight	Bulk	Strategic Matl's	Novel Fuel Compatibility	**Projected Cost**	**Earliest Availability**
1969 Otto ICE*	P	P	E	E	E	F	E	PRE-1969
1976 Otto ICE	P	F	G	G	P	F	G	1976
Stratified Charge	G	F	G	G	G	F	F	1980
Light-Weight Diesel	G	F	G	G	G	F	F	1982
Advanced Gas Turbine	G	G	G	G	F	G	G	1984
Rankine	F	E	P	P	G	E	G	1987
Stirling	E	E	F	F	F	E	P	1987
Closed Brayton	G	E	P	P	F	E	P	1987
Heat/Electric or Heat/Fly-wheel Hybrids	F	F	F	F	G	F	F	1982

*Internal Combustion Engine.

Ranking: E = Excellent; G = Good; F = Fair; P = Poor

SOURCE: Reference 288, Table IV-2. Cf. Table 5-2, p. 5-11.

Gas Turbine (Open-Cycle Brayton). At present this engine is widely used in jet aircraft turboprops, aircraft auxiliary power units, high-speed boats, and some experimental automobiles (Chrysler). DOD's Advanced Research Projects Administration is also sponsoring exploratory development of all-ceramic turbines by Ford, and Greyhound announced a turbine engine for buses in August 1974 (Public Transit Report, 31 August 1974, p. 5). In the automobile application, NO_x emissions appear at present to be the main problem. While the engine has multi-fuel capability, no advantages in fuel consumption are forecast. This engine is also more expensive than today's gasoline engines.

Advanced Rankine. Closed Rankine cycle engines, i.e., steam engines, are the oldest type of engine used for stationary power plants and are still quite common. EPA is sponsoring research in mobile plant applications (through Aerojet General and others), but weight, bulk, temperature requirements, and poor fuel economy are difficult problems to resolve. UMTA also had a steam-bus R&D program. The main advantage of the Rankine engine is its multi-fuel capability and its ability to meet the 1976 emission standards. First cost and fuel consumption costs will be higher than for equivalent gasoline engines.

Stirling Cycle Engine. Most of the R&D on the Stirling engine has been carried out by Dutch Philips. Development work on truck-size engines is being carried out in Germany and Sweden, and Ford has a minimal R&D effort. The weight of Philips' Stirling engine is below 4 lb./hp, exhaust emissions are well below the 1976 EPA standards, and fuel economy is excellent (better than diesel). Because its manufacture requires expensive materials (e.g., nickel), this engine will be expensive. The main advantage of Stirling engines will be in applications where a large amount of running time is spent at less than optimum speed or at idle, e.g., in transit buses. The earliest forecast availability is 1987.

Closed-Cycle Brayton. NASA has sponsored the bulk of R&D for 20-140 hp closed-cycle Brayton engines for space applications. At 30 percent thermal efficiency, these have been operating with no maintenance for 5 years. The engine has the following advantages for ground transportation:

1. very small size;
2. rapid reaction to changes in power;
3. ability to use open-cycle gas production technology;

4. low fuel consumption (lower than Rankine, about 3/4 of diesel);
5. almost no emissions (HC: 0.01 g/mi.; CO: 0.36 g/mi.; NO_x: 0.14 g/mi.).

Restrict Maximum Speeds (6.1.4)

Actual observation in Los Angeles by CalTrans during periods when the 55 mph speed limit was actually obeyed indicated that traffic was traveling much more smoothly, even at peak hours, and that motorists were finding that trips took less time than under the earlier 65-70 mph limit (personal communication to INTERPLAN from CalTrans). The indefinite extension by the Congress in September 1974 of the 55 mph speed limit (Los Angeles Times, 12 September 1974) will allow these benefits in mobility to be continued. Reducing the speed limit from 65 mph to 55 mph results in an 11 percent reduction in fuel consumption (Chrysler tests, 301, p. 490), or 300,000 barrels of gasoline per day. Since this amount is roughly equivalent to the 1973-74 winter gasoline shortfall, the gasoline shortage problem could be eliminated by reducing speed for one year (Union Oil testimony, 301, pp. 389-91). Driving at 55 mph (instead of 65 or 70) also reduces the cost of making a given trip by approximately 10 percent of the total fuel cost, with a somewhat greater proportional increase in driving time.

Educate Car Owners to Optimize Fuel Use (6.1.5)

The education of the public is an indispensible component of almost any action which UMTA/EPA/FEA may want to undertake, either jointly or singly. Besides educating car owners to optimize fuel use, the following educational themes come to mind:

General Public

1. The economic and urban driving advantages of small automobiles.
2. The economic and environmental advantages of keeping one's car in good working order, with properly inflated tires, well-tuned engine, etc.
3. The economic and safety advantages of observing the 55 mph speed limit.
4. The economic advantages of carpooling and transit use.
5. The balance of payments and inflation penalties of importing oil.
6. The advantages of driving less by planning ahead to combine trips.

It is INTERPLAN's opinion that all three agencies should redouble their public education efforts to reinforce their ongoing programs. This recommendation applies especially to UMTA which, of the three agencies, has the least regulatory responsibility and authority. As pointed out in Volume 4, UMTA is required by law to offer advice, guidance and leadership in the field of better public mass transportation. Many of the studies it has sponsored have educational value for operators and local officials, but the time lag between the consultant's delivery of a report and its submission to NTIS for printing and distribution can be as long as 18 months. These delays should be shortened, and more publicity should be given to the energy-saving, cost-saving advantages of transit and paratransit.

It is important that any public education program be a strong, on-going effort and not just a temporary emergency appeal. During the 1973-74 winter fuel shortage, for example, pointers on how to economize fuel by keeping one's car in shape were widely publicized by the news media, and UMTA and FHWA undertook a nationwide crash promotion program for carpooling. Carpools gained some popularity, and in some areas fuel consumption decreased by as much as 10 or 15 percent. Unfortunately, as soon as gasoline became available again, the momentum of the educational effort was lost. The present slightly lower level of demand for gasoline relative to last year, due to the increased cost per gallon and to inflationary erosion of income, could surely have been lowered even more if the educational effort had been sustained.

Legislate Mandatory Maintenance and Inspection (6.1.6)

One harsh but effective way to educate the driving public about the importance of having their cars properly tuned would be to introduce a mandatory periodic testing of engine fuel performance. Such inspections, which could be performed simultaneously with periodic safety inspections where they are required, or with proposed emission inspections, would also provide an opportunity to educate auto drivers about the basic points of auto care, fuel economy, choice of proper (radial) tires and maintenance of proper pressure levels, engine starting procedures, and similar subjects. The fuel performance inspection would have as its object the verification that the car is obtaining the mileage advertised for it by the manufacturer and tested and certified by EPA. It is INTERPLAN's feeling that if mandatory periodic safety and emission inspections are to become routine, there are very good grounds for adding some type of fuel economy test as well.

Furthermore, since there is a direct tradeoff between fuel economy and reduction in emissions (especially NO_x), once emission and fuel use standards are established, local authorities would have a firm basis for introducing periodic inspections of automobiles so that the optimal balance between the two goals (better fuel economy and lower emissions) is achieved. Defining this optimum tradeoff is, of course, a matter of developing a common strategy between EPA and FEA.

RESTRICT VEHICULAR USE (6.2)

Legislate Mandatory Carpooling (6.2.1)

Carpooling, one of the most effective and immediate ways of lowering fuel consumption, is treated at some length in Section 3 (see "Increase auto occupancy" [3.1]). The stress here (6.2.1) is on the term "mandatory". Although the impact of widespread mandatory carpooling on both gasoline demand and air quality would be very favorable, it, like fuel rationing (6.2.2) is not likely even to be considered short of a national or regional emergency. Where such an emergency exists, as in the California South Coast Air Basin (Los Angeles area) with regard to air quality, however, making carpooling mandatory for large firms could become standard practice.

In the South Coast Air Basin, for example, every employer who has more than 100 employees in a single location, or more than 50 vehicles in his fleet, is going to have to develop an emergency plan by spring of 1975 to drastically reduce pollution during heavy smog periods, including mandatory carpools for his employees and closure of the office or plant if pollutant levels go high enough (Los Angeles Times, 19 September 1974). In Los Angeles County alone, about 5,000 employers are large enough to qualify. These firms' experience with this program, which was imposed by local air pollution officials, will be of interest in evaluating future applications of this action.

Restrict or Ration Fuel Supplies (6.2.2)

The Administration was ready to introduce fuel rationing in early 1974; had the OPEC oil embargo lasted a few months longer, there is not much doubt that it would have been introduced. Many top-level economists regret now that it was not introduced, and Congress will probably be requested soon to authorize standby gasoline rationing authority, since there is some doubt about the government's current authority to order gasoline rationing (Los Angeles Times, 24 September 1974).

It is clear that the current $3 billion balance of payments deficit, more than half of it due to direct oil imports, cannot continue for long. The era of unlimited supplies of oil and of other imported raw materials is coming to an end. Critical chortages of minerals, timber, and other materials are

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likely to occur within five years, according to John Kyl, Assistant Secretary of Interior (Los Angeles Times, 30 September 1974). How the U.S. will deal with these shortages, and how well, remains to be seen. Demand will have to be limited to available supply, whether this is done administratively by rationing, in the marketplace by allowing prices to rise (see action 3.2.3, increase fuel costs), or by arousing public spirit through a nationwide call to conserve (see action 6.1.5, educate car owners to optimize fuel use). Most likely, gas rationing will come last; even the EPA has decided that this type of measure is "per se unreasonable" (337, p. 3).

INTRODUCE NOVEL, NON-PETROLEUM-BASED VEHICULAR PROPULSION SYSTEMS (6.3)

There are two approaches to conserving petroleum by switching to other fuels: development of synthetic and natural gas-based fuels, and increasing the production of already available electric cars while bringing advanced electric propulsion systems to the production stage. Besides directly reducing the demand for gasoline, these strategies would also reduce vehicular emissions.

Convert to Alternative Fuels (6.3.1)

GASEOUS FUELS. Compressed natural gas (CNG), and liquified natural gas (LNG) are cleaner burning than gasoline because they ignite more rapidly, and combustion is more complete. Basic conversion requires installation of a special carburetor, special fuel tanks (including pressure tanks for CNG, cyrogenic tanks for LNG), pressure regulating devices, shut-off valves, and fuel lines. More complex conversion can require installation of a venturi carburetor, exhaust gas recirculation, exhaust air-thermal reactor system and catalytic converter. The cost of basically modifying a "standard" automobile to CNG or LNG ranges between $350 and $500. Emissions from completely modified vehicles would meet EPA standards for 1975 and 1976 gasoline-powered vehicles (257). Most importantly, the fuel supplies, distribution system and conversion equipment are readily available for conversion to gaseous fuels.

METHANOL AND ETHANOL. Gaseous fuels still require the use of a relatively limited natural resource. Based on abundant resources of coal, nuclear energy, and solar energy, a number of synthetic fuels have been investigated for auto use (25). In the short term, methanol and ethanol appear to be the most attractive alternatives, and hydrogen appears to be a worthwhile goal for the long term. For the two alcoholic fuels, weight, volume, cost, and contamination by water still present problems if their pure use as fuels is desired. Ethanol and methanol require 1.2 and 2.1 times more weight and 1.6 and 1.8 times more volume than gasoline, respectively. Synthetic methanol costs about half again as much as gasoline to produce ($2.10 per million Btu vs $1.32 per million Btu), and ethanol nearly six times as much ($7.30). However, adding up to only 20 percent methanol would increase the basic cost of gasoline by only 5 percent. Since alcohols are miscible with water, special precautions are needed to prevent contamination. But use of these fuels in volume blends up to 35 percent deserves serious consideration in stretching current fuel supplies. Most of today's vehicles could operate with methanol additions, and could even run on pure methanol with perhaps minor retrofitting.

HYDROGEN. There is a serious body of opinion, especially among scientists of the principal manufacturers of electric power generation and transmission equipment in America and Europe, that "the only way to go in the future is the hydrogen way." The main argument is that by the end of the century, large-scale nuclear power generation will be satisfying a large proportion of our energy needs, and that a considerable amount of that power will be devoted to producing hydrogen from sea water to be used as fuel. At the same time, ammonia will be produced even more economically than today for use in fertilizers. A recent study shows that hydrogen can be inexpensively transported across the country through pipeline systems, if necessary using the existing natural gas pipeline system.*

Hydrogen, while in many respects an "ideal" fuel, is difficult to store in vehicles (25). Compressed hydrogen gas is out of the question: 40 cylinders weighing 125 lbs. each would be needed to produce the equivalent of 20 gallons of gasoline. Liquid hydrogen, however, would require a tank capacity of 73 gallons, about three times that needed for gasoline. This amount of fuel would weigh only 43 lbs., but would require a vacuum-insulated tank comparable to those needed for the natural gas-based fuels (200 lbs. for a 66-gallon capacity). Hydrogen produced electrolytically may be economically attractive but not competitive with gasoline; if made from coal, it would cost less than gasoline ($1.00 per million Btu).

Several attempts have been made to use hydrogen to power conventional engines, including use of a third valve to inject hydrogen directly into the combustion chamber, injecting a regulated supply directly into the inlet ports, and using a modified LPG or propane carburetor. Some of these methods, which have been tried at UCLA and elsewhere, appear quite promising. GE researchers believe that the conversion from conventional to hydrogen distribution (refueling) should not present any serious difficulties. Just as now most gas station pumps are being equipped with special nozzles to dispense unleaded gas, the "gas" station of the 1980s could stock standard size vacuum-insulated tanks filled with liquid hydrogen which would be plugged into a car's fuel system. The whole operation should not take longer than filling a 20-gallon tank does now. If GE, Westinghouse, Siemens & Halske in Germany, and others who are developing this power source are on the right track, then our civilization is moving toward a power environment in which nuclear power produces hydrogen and ammonia for fuel use. Hydrogen would power vehicles and stationary power plants where direct application of nuclear power is impracticable; ammonia would substitute for petrochemicals in satisfying the increasing demand for fertilizers. There is not much doubt that the OPEC countries understand this situation quite clearly. Since their oil resources are not inexhaustible, and since nuclear power (eventually fusion power in the early 21st century) will take over in 10 to 20 years, they have at most 20 years to "unload" their oil on the market at maximum prices.

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*R. A. Reynolds and W. L. Slager, "Pipeline Transportation of Hydrogen" (Santa Barbara, Calif.: General Electric Company, TEMPO [1974]).

Two basic parallel strategies for urban transportation emerge from these broad considerations. For the next 10 to 15 years, urban mobility will have to be largely based on gasoline, available only at exorbitant prices. Therefore the broad principles of thrift will have to be applied: smaller cars, common-sense application of EPA exhaust emission standards, introduction of methane and propane additives, speed restrictions, and above all reeducation of the public from the current orientation towards growth to the realities of long-term shortages. If these measures and others recommended by Dixy Lee Ray (242) are applied soon, wisely, and energetically, the U.S. bill for imported oil may be eliminated by 1990.

The long-term strategy will be to take maximum advantage of abundant nuclear power. In contrast to the limited supplies of crude oil, supplies of uranium from sea water are truly inexhaustible; after all, seven-eighths of the globe is covered with sea water.* As much urban traffic as possible should be fully electrified, hence the importance of acquiring rights-of-way now for future rail, light rail, dual mode and PRT systems. Those vehicles which cannot be electrified may use hydrogen propulsion systems.

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*See General Electric Company, TEMPO, Future Environments in Energy Technology (Santa Barbara, Calif., 1967).

Increase R&D and Produce Electric Cars (6.3.2)

INTRODUCTION. While the manufacturers of electric power generation equipment seem to agree that "hydrogen is the way to go", automobile producers think that the future, at least to a certain extent, lies in electric cars. GM laboratories in Santa Barbara, Ford, and Alsthom in France (in conjunction with Peugeot) have for years been energetically developing a better electrical battery, i.e., one which would be less costly, would weigh less, would last longer, and above all would have greater power density, i.e., be able to store more usable energy in the battery's available weight and space.

In 1968, members of INTERPLAN's staff participated in a comprehensive survey of the state of the art of electric batteries in the U.S. and Europe as part of a broader study.* No country could report any promising results. Personal visits of our company's staff to French manufacturers in 1972, who are working closely with General Motors, revealed many ideas and promises but nothing concrete. Sources reviewed in the course of the Volume 4 study indicated that low performance battery-powered automobiles for city driving are currently in limited production and could be in mass production by 1976 (301, pp. 124 and 127). A prototype advanced battery-powered vehicle with sufficient power and range to serve as a full-fledged auto can be expected by 1980; such a vehicle, powered by a sodium-sulfur or lithium-sulfur battery, could be in mass production by 1984. Fuel cells perform better, last longer, and require less expensive electro-catalysts than batteries, but are much further in the future: it may be 10 to 15 years before a suitable prototype is available (301, p. 124; 40). All electric powerplants are heavier and more expensive than the uncontrolled gasoline engine.

Figure 6-1, reproduced from Reference 89, compares the energy requirements of internal combustion and electric vehicles. While the internal combustion engine needs all of its energy input in the form of petroleum, an electric vehicle can rely exclusively on power produced by coal and nuclear fuels, providing it is available in sufficient quantities. Most forecasts do not see this occurring until the mid or late 1980s. The coal industry is now producing 20 percent less coal than a few years ago, and the mechanization and automation of coal mines will take at least a decade, although

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*General Electric Company, TEMPO, The Future of Power Generation, prepared for Koninklijke Machinefabrik Stork N.V. (Santa Barbara, Calif., 1968).

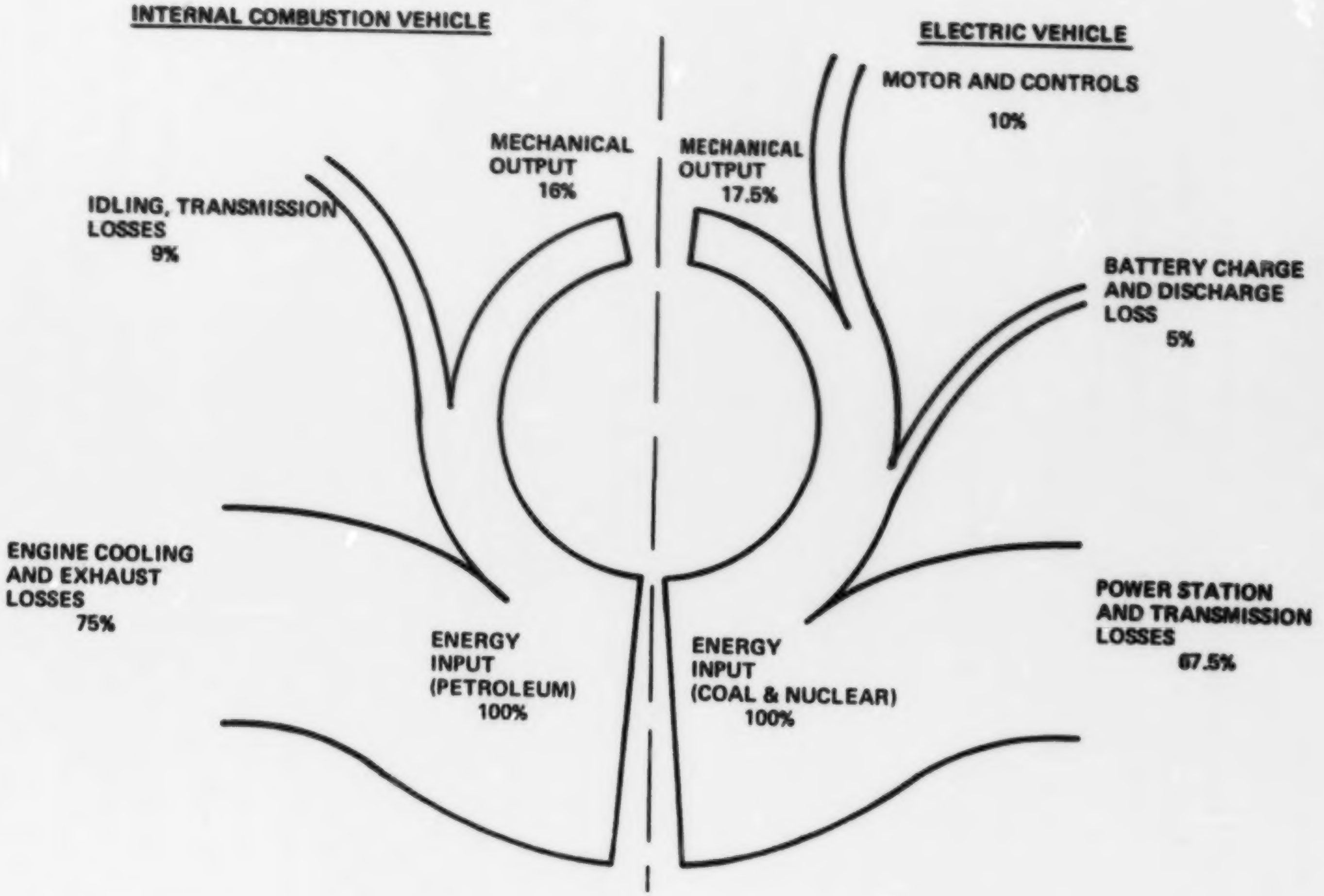

Figure 6-1. Energy utilization for electric vs internal combustion engine vehicles.

SOURCE: Reproduced from Ref. 89, p. 19.

70 percent of U.S. electrical energy production now relies on coal. The availability of nuclear energy at present is minimal (less than 5 percent) and cannot be increased quickly. The rest of U.S. power generation is based on either oil or natural gas.

Not only can electric vehicles use non-petroleum energy sources, but their overall energy efficiency is somewhat better. The compound efficiency of a battery-powered car from the terminals of the generating power station to the vehicle's road power is about 44 percent, including all accessories. Since non-nuclear electric power plants have a reference efficiency of 35 to 40 percent, the overall efficiency of electric cars is between 15 and 18 percent, compared to about 14 percent for a typical heat engine car (288).

The basic questions regarding electric vehicles are: (1) when will better batteries become available? (2) When will nuclear power for night charging of batteries be available?

STATE OF THE ART. A General Research Corporation (Santa Barbara) draft report for EPA presents the following summary of anticipated developments in battery state of the art:*

1975 Current lead-acid (Pb-H_2SO_4) batteries with minor improvements. They will provide about 60 watts per pound weight and 20 watt-hours per pound.

1980 Nickel-zinc batteries are likely to take over. They should be about twice as good as lead-acid (100 watts/lb., 50 watt-hours/lb.).

1980-1985 Zinc-chloride (Zn-CL_2) will offer some improvements over nickel-zinc.

1985-1990 Lithium-sulfur (solid electrodes) may come into use culminating after 1990 in Li-S in molten state. Such a battery will delivery more than 100 watts/lb., and 200 watt-hours/lb., and will last for at least three years (or approximately 1,000 charging cycles) in auto use. The design aim is to price the battery (at current prices) at no more than $1/lb.

Battery-propelled cars will have to be small to attain reasonable range and performance. The comparative energy consumption of small cars is shown in Figure 6-2, reproduced from the General Research report. It should be noted

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*William Hamilton, Impacts of Electric Car Use in Los Angeles, prepared for presentation at the U.S. Environmental Protection Agency, Division of Advanced Automotive Power Systems Development, Contractors Coordination Meeting, 16 May 1974 (Santa Barbara, Calif.: General Research Croporation).

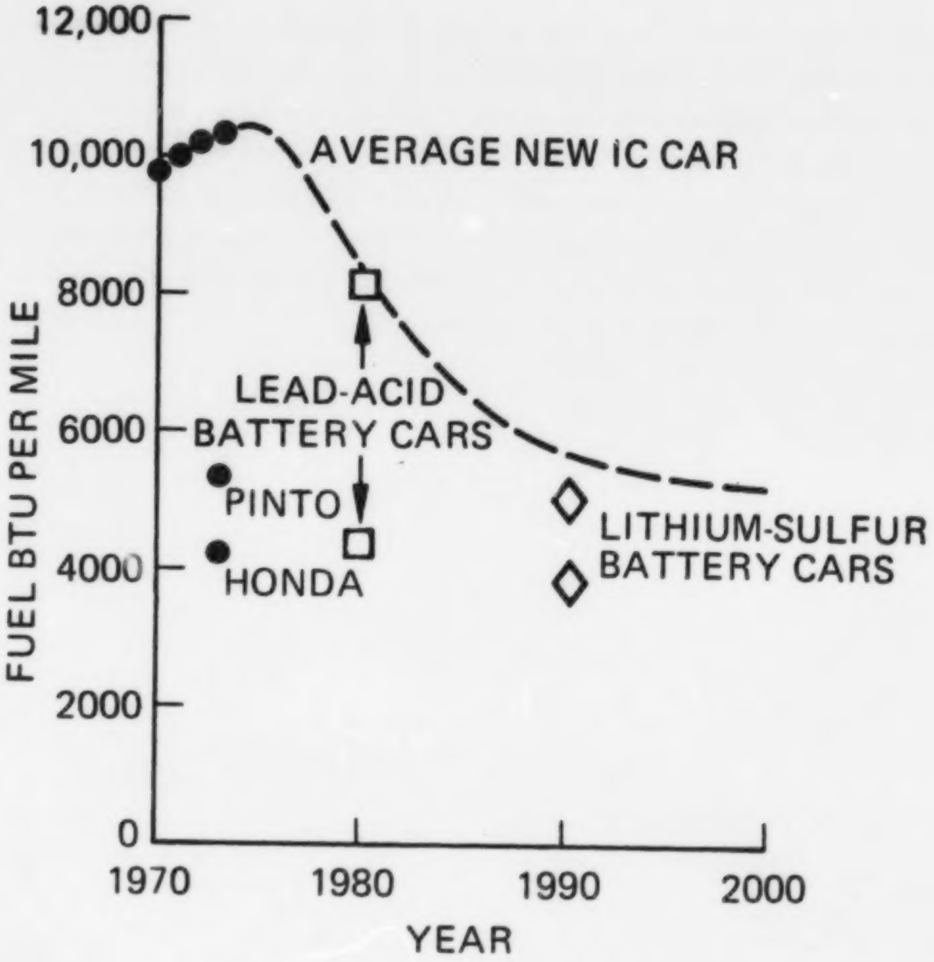

Figure 6-2. Comparative energy consumption of internal combustion and battery-powered cars, 1970-2000.

SOURCE: Reproduced from Hamilton, op. cit., Chart 7.

that by the 1990s the average performance of the internal combustion vehicle is expected to improve by at least 50 percent. However, by then, lithium-sulfur batteries should have an edge of some 10 to 20 percent. Besides lower energy consumption, the advantage of electric cars will be their quietness and freedom from emissions at the vehicle. It will be the ideal environmental car.

How much will electric cars cost? Initially, they will be more expensive than their internal combustion counterparts, but they will last longer and will require less maintenance. Battery depreciation is the main cause of the significantly higher cost. The best estimates available are shown in Figure 6-3, also from the GRC report. Annual mileage is a decisive factor. At the present average of 10,000 miles per year, lead-acid battery-powered cars will find it difficult to compete with the average conventional car; the cost of the battery alone would be $1200-1600, and it would have to be replaced every 2 to 3 years. Thus amortization of batteries alone would amount to 5-8¢/mile. 1990 conventional subcompacts will definitely be cheaper, unless lithium-sulfur battery development is successful.

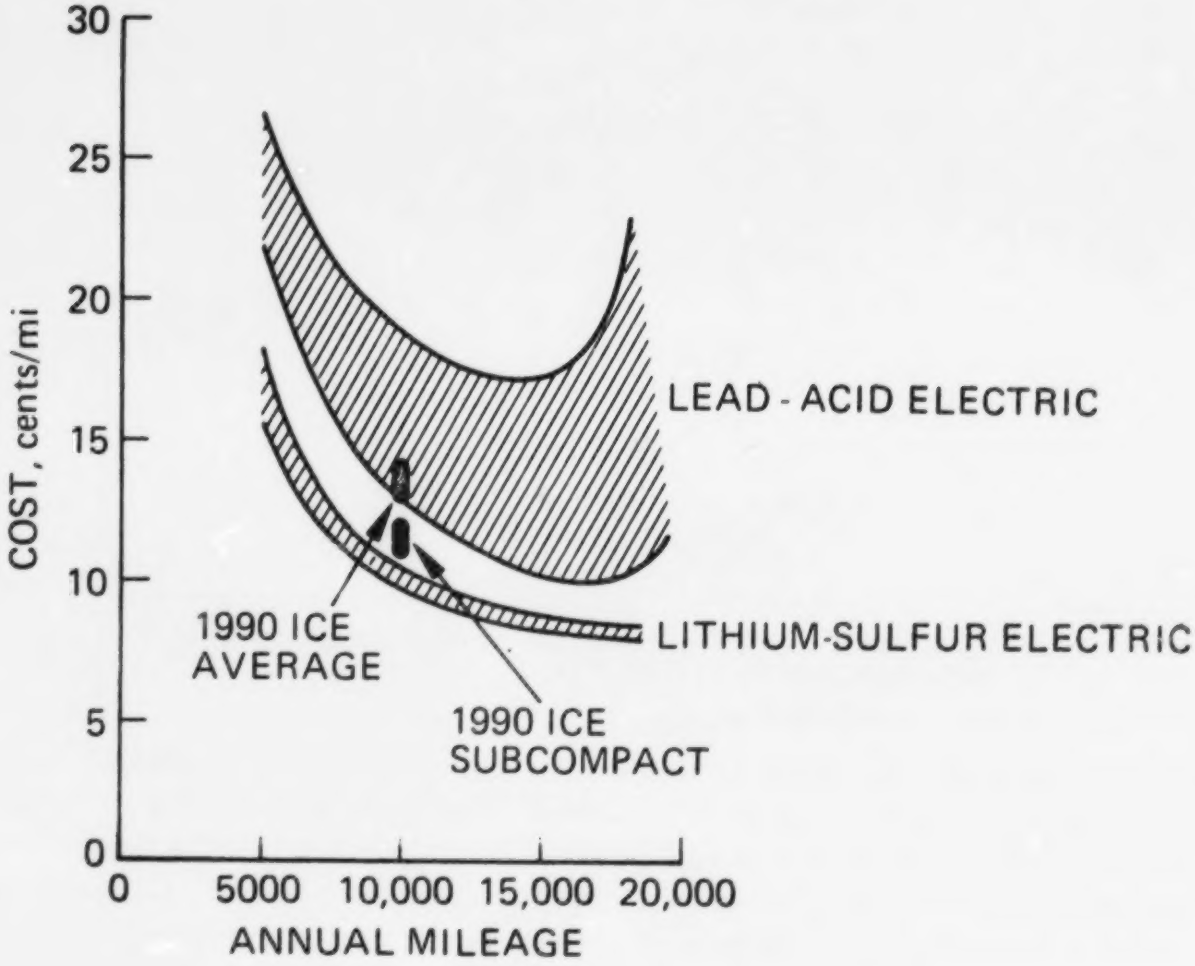

Figure 6-3. Comparative operating costs for internal combustion and battery-powered cars as a function of annual mileage.

NOTE: ICE estimates assume gasoline prices of 50-80¢/gallon.

SOURCE: Reproduced from Hamilton, op. cit., Chart 12.

The GRC report concentrates on the impact of electric cars in the Los Angeles area. The future applicability of electric cars for private use is summarized in Table 6-3. Even if electric cars are restricted to second-car use by households with single-family dwellings having off-street parking so that overnight recharging could be easily arranged, a million Los Angeles automobiles could be electric in 1980 and much larger numbers in 1990 and 2000 when high-performance batteries will increase the range to the point where it is adequate for first-car use in most households.

Table 6-3. Potential market for electric cars in the Los Angeles area.

	1980	1990	2000
Electric cars, millions	1	3	6
Percent of total autos	17	46	74

The validity of this estimate depends on many factors. Future environmental policy is one of the most important. If present transportation control plan strategies cannot sufficiently reduce emissions, special policies encouraging electric cars could be implemented, such as a tax calculated to eliminate the cost disadvantage of electric cars. To quote the GRC report:

> "Elimination of the cost disadvantage for the lead-acid battery cars would require a gasoline tax of at least $1.70 per gallon or a purchase tax of $2400, even given the lower cost associated with the most optimistic battery cycle life. The impact of any such taxes obviously becomes a major consideration in the overall cost and benefit assessment for electric cars."

Other applications of electric propulsion, apart from the use of electric vehicles as second cars, would be in delivery vans, which characteristically cover a specific (limited) daily mileage and spend considerable time idling or in traffic congestion. Even the lead-acid batteries of today could be applied to electric utility meter readers and postal delivery vans; they are already used for milk delivery trucks. A second important application is in a very small vehicle, like a golf cart, to serve as a link between public transit stations and the residences of commuters. Similar vehicles could be used by people who at present cannot obtain a drivers license because they are too old, too young, or handicapped. Operating with a 20-mile-per-hour speed limit on exclusive rights-of-way, such vehicles could provide mobility to those who now lack it, an important objective of UMTA.

AVAILABILITY OF ELECTRIC POWER. In the Los Angeles area, there will not be enough electric power of nuclear or coal origin to charge car batteries at night until after the 1990s, according to the GRC report. Forecasted hourly electricity demand and supply in Los Angeles for the summer of 1990, when air conditioners are working day and night, is shown in Figure 6-4. The daily peak load requires support by oil-fired power stations, while hydro, nuclear, coal and gas power will be just sufficient to keep air conditioners and night services supplied between midnight and 6 AM. Thus, if an extra load is required to recharge electric cars, oil would also have to be burned at night. This situation is not expected to change until later in the 1990s.*

What is true for Los Angeles does not need to apply to other metropolitan areas of the country. The heavy reliance on oil by power stations represented in Figure 6-4 is common in Southern California, but not necessarily in other parts of the country. Thus Seattle, which derives the bulk of its power from hydroelectric sources, is ready for night charging of electric batteries now, except during periods of exceptionally low rainfall such as last winter. In the midwest, most power stations rely on coal, and close to 100 nuclear power stations are on order or in planning stages. Thus, "readiness for electric cars" in these areas is likely to occur somewhat sooner than in California.

Taking North America as a whole, recent estimates, including those of "Project Independence", foresee a growth in electricity generation of some 5 percent per annum (as compared to 3 percent for energy growth as a whole) over the coming decade. By 1980, total gross electricity generation should reach 4,000 TWH, of which 60 percent will rely mostly on coal, 15 percent on hydro energy, 25 percent on nuclear power stations, and the rest on oil and natural gas (OECD, 24th Survey of Electric Power Equipment, 1971). Intensive installation of nuclear equipment will begin in 1975, and by 1980, 80 percent of new

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*It should be noted that this period coincides with the possible availability of a dual-mode car, which may well be battery powered when not on an electric guideway (see 144b). The dual-mode vehicle's charging load will not be very large, since the battery is likely to be small, and its use for travel to and from work (or to and from a public transit pick-up point) is likely to draw electricity before and after the beginning of the daytime peak load. Therefore, both fully self-propelled electric vehicles and dual-mode (dual-control) vehicles could be of some significance in saving petroleum-type fuel in the Los Angeles area in the 1990s.

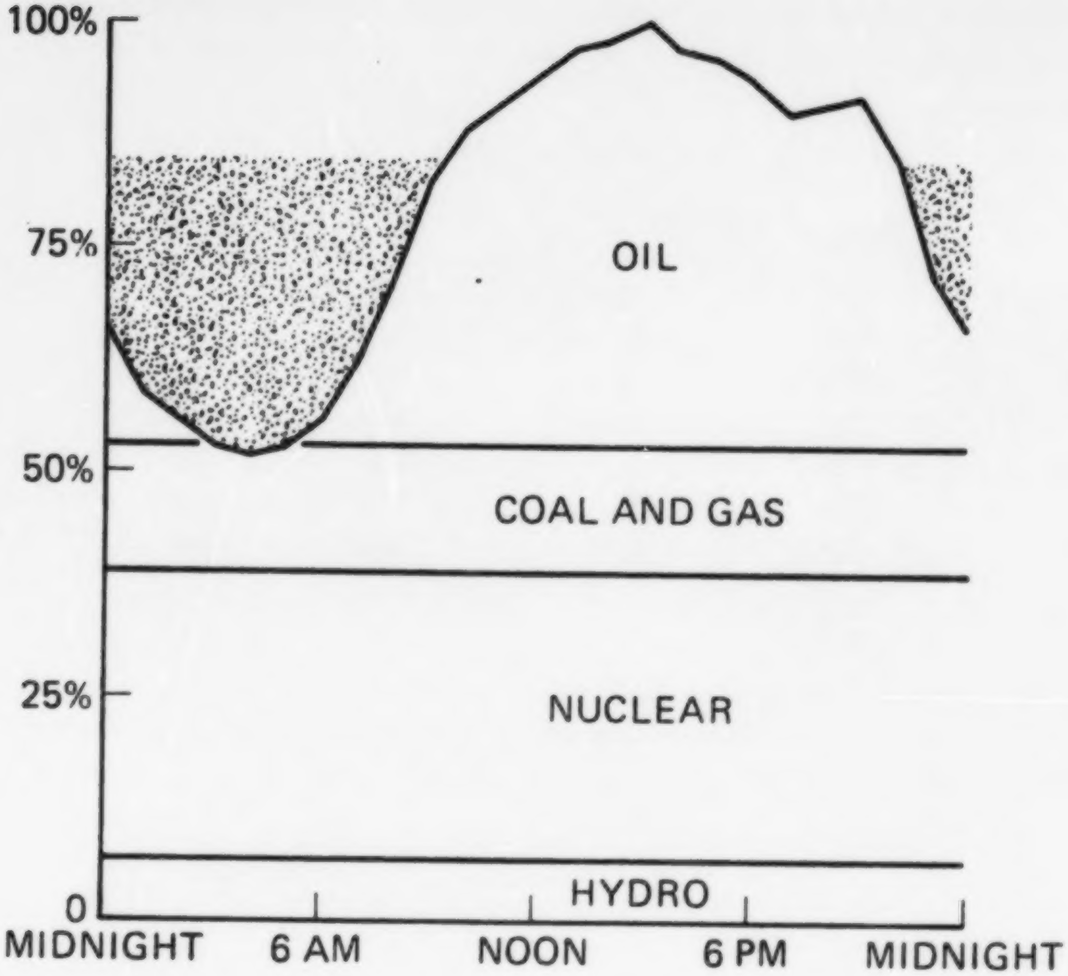

Figure 6-4. Forecast hourly electricity demand and supply in Los Angeles, August 1990.

SOURCE: Reproduced from Hamilton, op. cit., Chart 8.

generation capacity being installed will be nuclear. The Atomic Energy Commission Bulletin of March 15, 1974 provides the following forecast of nuclear plant capacity:

Table 6-4. Forecast nuclear plant capacity, 1974-1987.

Year	Installed Capacity (GW)	Year	Initial Capacity
1974	20*	1981	122
1975	36	1982	155
1976	48	1983	175
1977	57	1984	188
1978	66	1985	194
1979	71	1986	195
1980	95	1987	197

*Out of 438 GW of total installed capacity as of January 1, 1974.

The overall impression is that by the late 1980s there will be sufficient quantities of nuclear energy to power electric cars, electrical subways, and light rail trains.

APPENDIX A

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